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ABSTRACT

These instructional materials include a teacher's guide designed to assist instructors in organizing and presenting an introductory course in general electronics focusing on semiconductor devices and circuits and a student guide. The materials are based on the curriculum-alignment concept of first stating the objectives, developing instructional strategies for teaching those objectives, and then evaluating based on the objectives. The course contains three units, each designed for use in more than one class period: Discrete Semiconductor Devices and Circuits, Linear Integrated Devices and Circuits, and Power Supplies. Each unit in the teacher edition includes some or all of the following: suggested activities, answers to assignment sheets, answers to written test, written test, unit evaluation form, teacher supplements, and transparency masters. In addition, the teacher edition includes a section on use of the publication, a competency profile, instructional and task analyses, academic and workplace skill classifications and definitions, a related academic and workplace skills list, and a correlation to the Electronics Industries Foundation skills list. Each of the instructional units in the student edition includes some or all of the following components of a unit of instruction: objective sheet, information sheet, assignment sheets, and job sheets. (KC)

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ED 410 410

General Electronics Technician
Semiconductor Devices and Circuits

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General Electronics Technician:

Semiconductor Devices and Circuits

Teacher Edition

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General Electronics Technician: Semiconductor Devices and Circuits

Teacher Edition

Table of Contents

Foreword vii
Acknowledgments ix
Use of introductory materials xi
Use of this publication xiii
Competency profile xvii
Instructional/task analysis xxi
Academic and workplace skill classifications and definitions xxix
Related academic and workplace skills list xxxi
Correlation of Electronic Industries Foundation skills list lix

Unit 1: Discrete Semiconductor Devices and Circuits

Suggested Activities 1
Answers to Assignment Sheets 9
Answers to Written Test 13
Written Test 21
Unit Evaluation Form 59

Teacher Supplements

1— Report on a Diode 63
2— Report on a Bipolar Junction Transistor 67
3— Report on a Field-Effect Transistor 69
4— Report on an Insulated Gate FET 71
5— Report on a Unijunction Transistor 73
6— Report on a Thyristor 75
7— Report on an Amplifier Application 77
8— Report on an Oscillator Application 79

Transparency Masters

1— P-N Junction 83
2— Biasing Effects on the P-N Junction 85
3— P-N Junction Diode Characteristic Curve 87
4— Zener Diode Characteristics 89
5— Tunnel Diode Characteristics 91
6— Various Transistor Cases 93
7— PNP Transistor Majority Current Carriers 95
8— Transistor Block Diagrams and Schematics 97
9— Comparison of Transistor Circuit Configurations 99
10— Correctly Biased Transistors 101
11— Electron Flow in NPN and PNP Transistor Circuits 103

Table of Contents (cont.)

12— Transistor Load Line 105
13— Junction Field-Effect Transistor 107
14— Metal Oxide Semiconductor Field-Effect Transistor 109
15 – Single-Ended Amplifier 111
16— Common-Base (PNP) Amplifier Circuit 113
17— Common-Collector (NPN) Amplifier Circuit 115
18— Common-Emitter (NPN) Amplifier Circuit 117
19— Feedback 119
20— Load Line for a C-E Amplifier 121
21— Frequency Compensation Networks 123
22— Push-Pull Amplifier 125
23— Complementary Symmetry Amplifier 127
24— Darlington Pair 129
25— Types of Oscillators 131
26— Types of Oscillators (Continued) 133
27— Crystal-Controlled Oscillator 135
28— Thyristors 137
29— Half-Wave Rectifier Circuits 139
30— Full-Wave Rectifier Circuit 141
31— Full-Wave Bridge Rectifier Circuit 143
32— Voltage Regulation 145
33— Zener Diode Regulators 147
34— Series Regulators 149

Unit 2: Linear Integrated Devices and Circuits

Suggested Activities 1
Answers to Assignment Sheets 9
Answers to Written Test 11
Written Test 19
Unit Evaluation Form 49

Teacher Supplements

1—Report on an Integrated Circuit 51
2—Report on a Sensor 55

Transparency Masters

1— Categories of Integrated Circuits 57
2— Monolithic Integrated Circuits 59
3— Hybrid Thick-Film Circuit 61
4— Features of a Typical Dual In-Line Package Integrated Circuit 63
5— Basic Differential Amplifier 65
6— Single-Input, Single-Output Differential Amplifier 67
7— Single-Input, Differential-Output Differential Amplifier 69
8— Differential-Input, Differential-Output Differential Amplifier 71
9— Operational Amplifier 73
10— Inverting Amplifier 75
11— Noninverting Amplifier 77
12— Gain Vs. Bandwidth 79
13— Two-Input Summing Amplifier 81
14— Four-Input Summing Amplifier 83

Table of Contents (cont.)

15 – Differential DC Amplifier ... 85
16— Hartley Oscillators ... 87
17— Colpitts Oscillators ... 89
18— Wein-Bridge Oscillator ... 91
19— Simplified Comparator Circuit ... 93
20— Basic Filter Configurations ... 95
21— Active Filters ... 97
22— AM Transmitter ... 99
23-– FM Transmitter ... 101
24— AM Superheterodyne Receiver Block Diagram ... 103
25— FM Broadcast Receiver Block Diagram ... 105
26— Modulation ... 107
27— Optical Communications System ... 109
28— Optical Fiber Light Transmission ... 111
29— Loss Factors of Fiber Optic Connectors ... 113
30— Loss Factors of Fiber Optic Connectors (Continued) ... 115
31— Refraction Indices ... 117

Unit 3: Power Supplies

Suggested Activities ... 1
Answers to Assignment Sheets ... 7
Answers to Written Test ... 9
Written Test ... 11
Unit Evaluation Form ... 21

Transparency Masters

1— The Transformer ... 23
2— Half-Wave Rectifier Circuits ... 25
3— Half-Wave Rectifier Output ... 27
4— Conventional Full-Wave Rectifier ... 29
5— Bridge Rectifier ... 31
6— Combination Power Supplies ... 33
7— Half-Wave Voltage-Doubler Circuit ... 35
8— Full-Wave Voltage-Doubler Circuit ... 37
9— Voltage Tripler ... 39
10— Simple Regulated Power Supply ... 41
11— Regulated Power Supply Block Diagram ... 43
12— Feedback Regulator ... 45
13— Switching Regulator ... 47
14— Load Protection ... 49

Foreword

General Electronics Technician: Semiconductor Devices and Circuits is the second in a three-book series that has been developed to replace *Basic Electronics* and *General Electronics Technician*, MAVCC's popular core publications for electronics technology. This volume contains three units that address semiconductor and integrated devices and circuits, power supplies, and the test and repair procedures associated with these devices and circuits. The other two books in the series are *General Electronics Technician Basic Electronics* and *General Electronics Technician: Digital Electronics and Introduction to Microprocessors.*

These new instructional materials acknowledge the expanding role of the electronics technician in this world of emerging technologies. They reflect technical developments in hardware and processes, as well as system changes within the industry, such as the increased role of microwave and fiber optic communications. They ensure that training needs as defined by industry are met by addressing the Electronic Industries Foundation proficiencies. Further, they incorporate improvements that MAVCC has made in our curriculum format to make the materials even more user-friendly and flexible while retaining the basic competency-based training concepts that have always been the foundation of MAVCC's instructional materials.

The success of this publication is largely due to the capabilities of the personnel who took part in its development. Appreciation is extended to them for their valuable contributions.

The *General Electronics Technician* series is designed for student use and to assist teachers in organizing and improving instruction. These instructional materials are based on the curriculum-alignment concept of first stating the objectives (objective sheet), developing instructional strategies for teaching to those objectives (information, assignment, and job sheets), and assessing to those same objectives (written test—a criterion-referenced evaluation instrument).

Every effort has been made to make these materials basic, readable, and usable. However, as with all instructional materials, teachers must localize and personalize these materials to meet their community, classroom/laboratory, and individual student's situation. Teachers are encouraged to supplement the materials and to develop strategies for motivating students.

Special attention should be given to the matrix identifying basic academic skills being reinforced in these instructional materials as well as the suggestions on ways to increase reinforcement of academic and workplace skills. By reinforcing these skills, the instructor should assist students in improving their employability skills.

As you use these instructional materials, we hope that you will find that they contribute to the quality of your program. If any problems occur or if you have any suggestions for improvement of the materials, please call or write us.

Jean McEntire, Chair
Board of Directors
Multistate Academic and
Vocational Curriculum Consortium

Clark R. Harris
Executive Director
Multistate Academic and
Vocational Curriculum Consortium

Acknowledgments

All major development projects such as the *General Electronics Technician* series are the product of the contributions of many individuals. This is particularly true in this case because these new instructional materials build on the foundation of two other MAVCC products: *Basic Electronics* and *General Electronic Technician*. Thus, a large part of the credit for these new products is due to the people who originally worked on the predecessor materials.

Basic Electronics was written by Lonnie Hartman and coordinated by Jane Huston. The planning and review committee consisted of:

Ralph Albin	Kirksville, Missouri
Ron Archuleta	Aurora, Colorado
Bob Bixler	Austin, Texas
Don Grob	Salina, Kansas
Horace Hamby	Natchitoches, Louisiana
Lonnie Hartman	Stillwater, Oklahoma
Joe Johnson	Harrison, Arkansas
Mike Julsen	Mason City, Iowa
Marshall Pudwill	Bismark, North Dakota
Leander Stachura	Lincoln, Nebraska
Richard Stedman	Mitchell, South Dakota

General Electronics Technician was written by Ron Vorderstrasse and coordinated by Jane Huston under the guidance of the same committee that planned and reviewed *Basic Electronics*.

Committee members responsible for overseeing the development of this new series include:

Scott Brillhart	Tulsa, Oklahoma
Jim Bullington	Stillwater, Oklahoma
Stan Creitz	Beloit, Kansas
Bill Dews	Shreveport, Louisiana
Lonny Gibbs	Tulsa, Oklahoma
Victor Greenwood	Springdale, Arkansas
Chuck Robertson	Sioux Falls, South Dakota
Frank Secor	Bellaire, Texas
John Smith	Anchorage, Alaska
George Stevenson	Oregon City, Oregon

The new *General Electronics Technician* series was developed under contract with Robert Hilley, who served as the project's technical writer. John Brun did the copy and technical editing and provided invaluable technical support. Kim Patterson was responsible for typesetting and page layout. Nancy Hilley was the graphics coordinator and primary technical illustrator. The series also contains graphics from other sources as acknowledged in copyright permission lines with the individual illustrations, as well as artwork from the original MAVCC publications that was generated by the Oklahoma Department of Vocational and Technical Education Graphics Division. The books were published by the Oklahoma Department of Vocational and Technical Education Print Shop, under the management of Danny Darrow.

Use of Introductory Materials

Introductory materials are included in the teacher edition only and contain useful information to assist administrators and teachers in planning for instruction.

In addition to the general information—such as the table of contents, foreword, and acknowledgments page—information is included on the following:

1. **Use of this publication**—Explains the components of a unit of instruction and how they should be used as part of the teaching/learning process.
2. **Competency profile**—Provides a record of student performance for each task included in a unit of instruction. This profile becomes a part of the student's permanent records and should be utilized when directing the student toward employment opportunities.
3. **Instructional/task analysis**—Provides a quick review of the contents of the publication; identifies cognitive (knowledge) skills and psychomotor (doing) skills addressed in each unit of instruction.
4. **Academic and workplace skill classifications and definitions**—Defines the basic-skill classifications used by MAVCC. Skill areas reflected by skill groups, subskills, and descriptions have been identified using *What Work Requires of Schools: A SCANS Report for America 2000* and *Workplace Basics: The Skills Employers Want*. These have been adapted by MAVCC.
5. **Related academic and workplace skills list**—Classifies unit tasks (assignment sheets and job sheets) according to the related academic and workplace skills being reinforced.
6. **Correlation to Electronics Industries Foundation skills list**—Shows how the competencies included in this publication satisfy the recommended training objectives developed by the Electronics Industries Foundation.

As you use these materials, it is hoped that they will provide useful information to meet a variety of needs.

Use of This Publication

Instructional units

General Electronics Technician: Semiconductor Devices and Circuits contains three units of instruction:

- Unit 1—Discrete Semiconductor Devices and Circuits
- Unit 2—Linear Integrated Devices and Circuits
- Unit 3—Power Supplies

Each instructional unit in a student edition includes some or all of the following components: objective sheet, information sheet, assignment sheets, and job sheets.

This teacher edition includes some or all of the following components for each of the five units of instruction: suggested activities, answers to assignment sheets, answers to written test, written test, unit evaluation form, teacher supplements, and transparency masters.

All of the unit components focus on measurable and observable learning outcomes. Teachers are encouraged to supplement, personalize, localize, and motivate with these materials in order to develop a complete teaching/learning process.

Units of instruction are designed for use in more than one lesson or class period of instruction. Careful study of each unit of instruction by the teacher will help to determine the following:

- Amount of materials that can be covered in each class period.
- Skills that must be demonstrated.
- Amount of class time needed for teacher demonstrations.
- Amount of class time needed for student practice.
- Supplementary materials, including print and nonprint media and equipment and supplies, that must be ordered.
- Resource persons who must be contacted.

Student-edition components

It is a challenge to keep students motivated. Instructors should supplement the student-edition components by providing the "why," personal experiences, and current information. Prepare for each unit by deciding how each component can best be taught. Allow students to become involved in preparing and planning their teaching/learning experiences.

Objective sheet. Each unit of instruction is based on performance objectives that state the goals for successful completion of the course. These performance objectives are stated in two forms: unit objectives, which state the expected performance of each student after completion of the unit of instruction, and specific objectives, which state what the student must do to reach the unit objective.

The objectives should be stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods. Teachers should prepare for each unit by deciding how each objective can best be taught.

Teachers should feel free to modify, delete, or add objectives in order to meet the needs of the students and community. When objectives are added, the teacher should remember to supply the needed information-sheet, assignment-sheet, job-sheet, and written-test items.

Information sheet. The information sheet provides the content essential for meeting the cognitive (knowledge) objectives of the unit. Teachers will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. Students should read the information sheet before the information is discussed in class. Space is provided in margins for students and teachers to add notes that supplement, localize, personalize, or provide information for the teaching of each objective.

Assignment sheets. Assignment sheets provide students with pencil-and-paper activities that give students the opportunity to make practical application of the knowledge in the information sheet. Criteria are provided to objectively evaluate student performance.

Job sheets. Job sheets are an important segment of each unit; they give the instructor direction as to the psychomotor skills to be taught and allow both the student and instructor to check student progress toward the accomplishment of those skills. Each job sheet provides criteria to allow the instructor to objectively evaluate student performance of a particular psychomotor skill. The instructor should discuss the equipment and materials to be used—emphasizing the specific equipment and materials available in the classroom and/or laboratory—and demonstrate the job-sheet procedure before having students practice the psychomotor skill.

Teacher-edition components

Suggested activities. The suggested activities assist teachers during the preparation stage of the teaching/learning process by providing an instructional plan, teaching suggestions, and a list of supplemental resources. Ways to integrate academic and workplace skills have been included in the teaching suggestions, and skill areas have been noted in bold. The teacher should read the suggested activities before teaching a unit and decide how each objective can best be taught. Time should also be allowed to obtain supplemental materials, prepare audiovisual materials, and contact outside resources. Duties of the teacher will vary according to the particular unit.

References used in the development of each unit are listed in the suggested-activities section, along with suggested supplemental resources that may be used to teach the unit. These materials can be used by the instructor to supplement her or his knowledge of the subject area or to help students with particular interests or objectives in the area covered.

Use of This Publication

The supplemental resources contain suggestions for media that the instructor may choose to use in support of the delivery portion of the teaching/learning process. Generally, none of the titles listed were more than approximately ten years old at the time of publication. This is done to provide the most current information in a contemporary style, as many students—especially adolescent students—may be distracted from the content of media by the presentation format, appearance of persons and equipment in the program, wear-and-tear of the physical medium, and other factors unrelated to the content information. However, many good films, videotapes, and similar media exist that were produced more than a decade ago, particularly those related to basic concepts such as Ohm's Law, electrical flow, fundamentals of semiconductor manufacture and common devices, etc. Instructors should assess the effectiveness of such programs within their specific course with their student population when selecting media to use.

Assignment-sheet and written-test answers. Assignment-sheet and written-test answers are designed to assist the teacher in evaluating student performances on the assignment sheets and written test.

Written test. This component is a criterion-referenced evaluation of every cognitive objective listed in the information sheet. If the instructor has added, deleted, or modified objectives, appropriate changes should be made on the written test. It is recommended that the test be divided into shorter tests covering three or four objectives at a time and given soon after those objectives are covered. A selection of test items from the units covered may be used for final tests at the end of each term if desired. The test is included in the teacher edition only, but duplication is permitted for student use.

Teacher supplements. Teacher supplements are optional materials for the teacher to use. They have three purposes: to provide the teacher with higher-level materials to stretch the advanced student, with remedial information or practice for the less-advanced student, and with state-of-the art information in which the instructor may not have background or with information that is not readily available in other sources. Some teacher supplements may be duplicated for student use and are marked accordingly.

Transparency masters. Transparency masters are used to direct the students' attention to the topic of discussion. Transparency masters may provide illustrations, charts, schematics, or additional information needed to clarify and reinforce objectives included in the unit of instruction.

General Electronics Technician: Semiconductor Devices and Circuits

Competency Profile

Name: ______________________________

Directions: Evaluate the student using one of the optional rating scales below. Write the appropriate numbers/letters to indicate the degree of competency achieved. The descriptions associated with each of the numbers/letters focus on a level of student performance for each of the tasks listed. The written-test score line is provided for optional teacher use. It may not be applicable in all cases.

Optional rating scales

Option A

Rating scale:
4 — **Skilled** - Can perform job with no additional training.
3 — **Moderately skilled** - Has performed job during training program; limited additional training may be required.
2 — **Limited skill** - Has performed job during training program; additional training is required to develop skill.
1 — **Unskilled** - Is familiar with process, but is unable to perform job.
0 — **No exposure** - No information or practice provided during training program; complete training is required.
NA — **Non-applicable.**

Option B

Yes — Can perform with no additional training
No — Is unable to perform satisfactorily

Unit 1: Discrete Semiconductor Devices and Circuits

______ 1. Use resource materials to determine pin configurations for common types of semiconductor devices.
______ 2. Interpret functions of electronic circuits constructed from discrete semiconductor components.
______ 3. Label the parts of a transistor circuit.
______ 4. Construct a load line for a common emitter amplifier circuit.
______ 5. Calculate the gain of amplifier circuits.
______ 6. Compute voltage, current, and power stage gain in decibels.
______ 7. Calculate the overall gain of multistage amplifiers.
______ 8. Identify types of transistors used in oscillators.
______ 9. Perform a static test of semiconductor diodes.
______ 10. Test a semiconductor diode and plot characteristic curves.
______ 11. Construct and test a half-wave rectifier circuit.
______ 12. Construct and test a full-wave bridge rectifier circuit.
______ 13. Test and replace light-sensitive devices.
______ 14. Test transistors.

______ 15. Construct and test a common-emitter circuit.
______ 16. Construct and test a common-base circuit.
______ 17. Construct and test a common-collector circuit.
______ 18. Plot a transistor output characteristic curve.
______ 19. Construct and test a single-ended amplifier.
______ 20. Construct and test a push-pull amplifier.
______ 21. Construct and test a two-stage, direct-coupled amplifier.
______ 22. Construct and test a Darlington pair amplifier.
______ 23. Construct and test a Hartley oscillator.
______ 24. Test and replace silicon-controlled rectifiers.
______ 25. Troubleshoot discrete solid-state device circuits.
______ 26. ____

______ Written-test score

Unit 2: Linear Integrated Devices and Circuits

______ 1. Calculate the closed-loop gain for an inverting and a noninverting amplifier.
______ 2. Calculate the output voltage of a DC summing amplifier.
______ 3. Determine specifications for commercially available op-amps.
______ 4. Construct and test an inverting amplifier.
______ 5. Construct and test a noninverting amplifier.
______ 6. Construct and test a differential amplifier.
______ 7. Construct and test a DC summing amplifier.
______ 8. Construct and test a Hartley oscillator using an op-amp.
______ 9. Construct and test a low-pass active filter.
______ 10. Construct and test a timer circuit.
______ 11. Troubleshoot linear circuits.
______ 12. ____

______ Written-test score

Unit 3: Power Supplies

______ 1. Calculate average voltages.
______ 2. Calculate rms values.
______ 3. Calculate ripple factors and percent regulation.
______ 4. Construct and test a voltage doubler circuit.
______ 5. Construct and test a capacitor filter circuit.
______ 6. Construct and test a Pi-section filter circuit.
______ 7. Construct and test a zener regulator.
______ 8. Troubleshoot power supplies.
______ 9. ____

______ Written-test score

Competency Profile

Comments: ____

____

Evaluator: ______________________________ **Date:** ______________

Permission to duplicate this profile is granted.

16

General Electronics Technician: Semiconductor Devices and Circuits

Instructional/Task Analysis

Related Information: What the student should know	Application: What the student should be able to do
Unit 1: Discrete Semiconductor Devices and Circuits	
1. Definitions of terms associated with discrete semiconductor devices and circuits	
2. Circuit applications of common discrete semiconductor devices	
3. Forward and reverse biasing	
4. Characteristics of semiconductor materials in constructing electronic devices	
5. Electrical flow in P- and N-type materials	
6. Characteristics of the P-N junction	
7. Diode operation	
8. Descriptions of discrete semiconductor diodes	
9. Uses of discrete semiconductor diodes	
10. Symbols for discrete semiconductor diodes	
11. Reasons for diode failure	
12. Structures and electrical equivalents of transistors	
13. Descriptions of types of transistors	
14. Symbols for types of transistors	
15. Characteristics of bipolar transistors	

Instructional/Task Analysis

Related Information: What the student should know	Application: What the student should be able to do
Unit 1: Discrete Semiconductor Devices and Circuits (cont.)	
16. Operation of an NPN transistor	
17. Operation of a PNP transistor	
18. Characteristics of transistor emitters, bases, and collectors	
19. Statements regarding the common-base circuit	
20. Statements regarding the common-collector circuit	
21. Statements regarding the common-emitter circuit	
22. Purpose of biasing in bipolar transistor circuits	
23. Methods for biasing bipolar transistors	
24. Statements regarding field effect transistors	
25. Statements regarding the common-gate circuit	
26. Statements regarding the common-drain circuit	
27. Statements regarding the common-source circuit	
28. Purpose of biasing in FET circuits	
29. Methods for biasing FETs	
30. Statements regarding insulated gate field effect transistors	
31. Correct handling precautions for IGFETs	
32. Characteristics of an ideal amplifier	

Unit 1: Discrete Semiconductor Devices and Circuits (cont.)

Related Information: What the student should know

33. Ways of classifying amplifiers
34. Operation of a single-stage amplifier circuit
35. Characteristics of power amplifiers
36. Transistor configurations of power amplifiers
37. Amplifier operating conditions
38. Methods of coupling transistor amplifier circuits
39. Classes of transistor amplifier circuits
40. Steps for troubleshooting transistor amplifier circuits
41. Operation of a unijunction transistor
42. Purpose of each section of an oscillator circuit
43. Decriptions of common oscillator configurations
44. Descriptions of thyristors
45. Symbols and electrical equivalents of thyristors
46. Rectified waveforms
47. Schematics for rectifier circuits
48. Schematics for types of voltage regulators

Application: What the student should be able to do

49. Use resource materials to determine pin configurations for common types of semiconductor devices
50. Interpret functions of electronic circuits constructed from discrete semiconductor components
51. Label the parts of a transistor circuit
52. Construct a load line for a common emitter amplifier circuit
53. Calculate the gain of amplifier circuits
54. Compute voltage, current, and power stage gain in decibels
55. Calculate the overall gain of multistage amplifiers
56. Identify types of transistors used in oscillators
57. Perform a static test of semiconductor diodes
58. Test a semiconductor diode and plot characteristic curves
59. Construct and test a half-wave rectifier circuit
60. Construct and test a full-wave bridge rectifier circuit
61. Test and replace light-sensitive devices
62. Test transistors
63. Construct and test a common-emitter circuit
64. Construct and test a common-base circuit

Instructional/Task Analysis

Related Information: What the student should know	Application: What the student should be able to do

Unit 1: Discrete Semiconductor Devices and Circuits (cont.)

	65. Construct and test a common-collector circuit
	66. Plot a transistor output characteristic curve
	67. Construct and test a single-ended amplifier
	68. Construct and test a push-pull amplifier
	69. Construct and test a two-stage, direct-coupled amplifier
	70. Construct and test a Darlington pair amplifier
	71. Construct and test a Hartley oscillator
	72. Test and replace silicon-controlled rectifiers
	73. Troubleshoot discrete solid-state device circuits

Unit 2: Linear Integrated Devices and Circuits

1. Definitions of terms associated with linear integrated devices and circuits	
2. Active and passive components	
3. Types of integrated circuit construction	
4. Ways of classifying IC packages	
5. Meaning of the elements in an IC part number	
6. Features of a dual in-line package integrated circuit	

Instructional/Task Analysis

Related Information: What the student should know	Application: What the student should be able to do
Unit 2: Linear Integrated Devices and Circuits (cont.)	
7. Number one pin on typical integrated circuit packages	
8. Advantages of using integrated circuit devices as compared to equivalent circuits consisting of discrete components	
9. Classifying ICs by the number of components they contain	
10. Guidelines for working with integrated circuits	
11. Common linear and digital integrated circuit devices	
12. Classifying amplifiers by their transfer functions	
13. Equations for mathematical functions performed by amplifiers	
14. Types of differential circuits	
15. Descriptions of types of differential circuits	
16. Components of an operational amplifier	
17. Functions of the components of an operational amplifier	
18. Parts of the symbol for an operational amplifier	
19. Operational characteristics of an operational amplifier	
20. Descriptions of input-output parameters of an op-amp	
21. Descriptions of dynamic parameters of an op-amp	

Instructional/Task Analysis

Related Information: What the student should know	Application: What the student should be able to do
Unit 2: Linear Integrated Devices and Circuits (cont.)	
22. Characteristics of an inverting amplifier	
23. Characteristics of a noninverting amplifier	
24. Open-loop and closed-loop operation	
25. Relationship among gain, bandwidth, and feedback in a closed-loop op-amp	
26. Characteristics of summing and difference amplifiers	
27. Schematics for types of sinusoidal op-amp oscillators	
28. Descriptions of nonsinusoidal op-amp oscillators	
29. Schematics for types of linear multivibrators	
30. Characteristics of comparators	
31. Descriptions of types of op-amp comparators	
32. Phase-locked loop operation	
33. Characteristics of active filters	
34. Schematics for active filter circuits	
35. Statements about transimpedance amplifiers	
36. IC switches and control devices	
37. Statements regarding IC timers	
38. Statements regarding IC counters	

Instructional/Task Analysis

Related Information: What the student should know	Application: What the student should be able to do
Unit 2: Linear Integrated Devices and Circuits (cont.)	
39. Function of IC transmitter and receiver devices	51. Calculate the closed-loop gain for an inverting and a noninverting amplifier
40. Operation and principles of an RF circuit	52. Calculate the output voltage of a DC summing amplifier
41. Operation and principles of an IF circuit	53. Determine specifications for commercially available op-amps
42. Waveforms for types of signal modulation	54. Construct and test an inverting amplifier
43. Characteristics of microwaves	55. Construct and test a noninverting amplifier
44. Uses of microwave circuits in electronic systems	56. Construct and test a differential amplifier
45. Parts of a fiber optic circuit	57. Construct and test a DC summing amplifier
46. Statements about fiber optic circuits	58. Construct and test a Hartley oscillator using an op-amp
47. Operation of IC sensor devices	
48. Types of IC sensor stimuli	59. Construct and test a low-pass active filter
49. Uses of photo-sensitive devices in linear circuits	60. Construct and test a timer circuit
50. Types of IC signal processing functions	61. Troubleshoot linear circuits
Unit 3: Power Supplies	
1. Definitions of terms associated with power supplies	
2. General functions of major power supply components	
3. Purposes of power supply circuits	
4. Function of bipolar power supply	

Instructional/Task Analysis

Related Information: What the student should know	Application: What the student should be able to do
Unit 3: Power Supplies (cont.)	
5. Characteristics of a half-wave rectifier circuit	18. Calculate average voltages
	19. Calculate rms values
6. Characteristics of a full-wave rectifier circuit	20. Calculate ripple factors and percent regulation
7. Characteristics of a bridge rectifier circuit	21. Construct and test a voltage doubler circuit
8. Output of combination rectifier circuits	22. Construct and test a capacitor filter circuit
9. Features of basic configurations of filter circuits	23. Construct and test a Pi-section filter circuit
10. Equation for calculating ripple factor	24. Construct and test a zener regulator
11. Three basic voltage multiplier circuits	25. Troubleshoot power supplies
12. Equation for calculating regulation	
13. Classifying regulator configurations as series or shunt regulators	
14. Operation of a feedback regulator	
15. Characteristics of switching regulators	
16. Schematic diagrams for protection circuits	
17. Steps for troubleshooting power supplies	

Academic and Workplace Skill Classifications and Definitions

Skill group	Subskill	Definition
Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
	Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner.
	Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
	Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Listening	Receiving, interpreting, and responding to verbal messages and other cues.
	Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
Thinking skills	Creative thinking	Using imagination to generate new ideas.
	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results.
	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
	Knowing how to learn	Using efficient learning techniques to acquire and apply new knowledge and skills.
	Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
	Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Career awareness, development, and mobility	Assessing self accurately, setting personal goals, establishing and implementing a plan, and monitoring progress.
	Integrity/honesty	Choosing an ethical course of action when faced with making a decision that may break with personal and societal values and recognizing the impact of violating these beliefs and codes on an organization, self, and others.
	Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.

Academic and Workplace Skill Classifications and Definitions

Skill group	Subskill	Definition
Interpersonal skills	Teamwork	Working cooperatively with others to reach a common goal.
	Coaching	Helping others learn new skills.
	Leadership	Communicating ideas to justify position; accepting responsibility for others; and encouraging, persuading, convincing, or otherwise motivating an individual or group.
	Negotiation	Resolving conflict between two or more individuals through discussion and compromise.
	Customer service	Working and communicating with customers to satisfy their expectations.
	Cultural diversity	Working well with men and women and with a variety of ethnic, social, or educational backgrounds.
Resources	Time	Selecting relevant, goal-oriented activities, ranking them in order of importance, allocating time, and understanding, preparing, and following schedules.
	Money	Using or preparing budgets, making forecasts, keeping records, and making adjustments to meet objectives.
	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Human resources	Assessing skills and distributing work accordingly; evaluating performance and providing feedback.
Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
	Organization and storage	Organizing, processing, and maintaining written or computerized records and other forms of information in a systematic way.
	Interpretation	Selecting and analyzing information and communicating the results to others.
	Processing	Using computers to acquire, organize, analyze, and communicate information.
Systems	Interrelationships	Knowing how social, organizational, and technological systems work and operate effectively.
	Monitoring	Distinguishing trends, predicting impact of actions on system operations, diagnosing deviations in systems' performance, and correcting malfunctions.
	Modification and design	Making suggestions to modify existing systems to improve products or services, and developing new or alternative systems.
Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
	Application	Demonstrating proper procedures for setting up and operating equipment.
	Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment, including computers and other technologies.

General Electronics Technician: Semiconductor Devices and Circuits

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 1:	**Discrete Semiconductor Devices and Circuits**		
Use resource material to determine pin configurations for common types of semiconductor devices (A.S. 1)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
Interpret functions of electronic circuits constructed from discrete semiconductor components (A.S. 2)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Systems	Interrelationships	Knowing how social, organizational, and technological systems work and operate effectively.

Related Academic and Workplace Skills List

Label the parts of a transistor circuit (A.S. 3)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
	Systems	Interrelationships	Knowing how social, organizational, and technological systems work and operate effectively.
Construct a load line for a common emitter amplifier circuit (A.S. 4)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
Calculate the gain of amplifier circuits(A.S. 5)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.

Related Academic and Workplace Skills List

Unit 1: Discrete Semiconductor Devices and Circuits (cont.)

Task	Skill group	Subskill	Description
	Thinking skills	Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
	Systems	Interrelationships	Knowing how social, organizational, and technological systems work and operate effectively.
Compute voltage, current, and power stage gain in decibels (A.S. 6)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Systems	Interrelationships	Knowing how social, organizational, and technological systems work and operate effectively.
Calculate the overall gain of multistage amplifiers(A.S. 7)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 1: Discrete Semiconductor Devices and Circuits (cont.)			
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Systems	Interrelationships	Knowing how social, organizational, and technological systems work and operate effectively.
Identify types of transistors used in oscillators (A.S. 8)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
Perform a static test of semiconductor diodes (J.S. 1)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 1: Discrete Semiconductor Devices and Circuits (cont.)			
		Application	Demonstrating proper procedures for setting up and operating equipment.
Test a semiconductor diode and plot characteristic curves (J.S. 2)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a half-wave rectifier circuit (J.S. 3)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
		Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results.
		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 1: Discrete Semiconductor Devices and Circuits (cont.)			
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a full-wave bridge rectifier circuit(J.S. 4)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Listening	Receiving, interpreting, and responding to verbal messages and other cues.
		Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 1: Discrete Semiconductor Devices and Circuits (cont.)			
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Test and replace light-sensitive devices (J.S. 5)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Test transistors (J.S. 6)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 1: Discrete Semiconductor Devices and Circuits (cont.)			
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a common-emitter circuit (J.S. 7)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
		Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 1: Discrete Semiconductor Devices and Circuits (cont.)			
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a common-base circuit (J.S. 8)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
		Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a common-collector circuit (J.S. 9)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 1: Discrete Semiconductor Devices and Circuits (cont.)			
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
		Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Plot a transistor output characteristic curve (J S 10)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 1: Discrete Semiconductor Devices and Circuits (cont.)			
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Interpersonal skills	Teamwork	Working cooperatively with others to reach a common goal.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
Construct and test a single-ended amplifier (J.S. 11)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
Construct and test a push-pull amplifier (J.S. 12)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.

Related Academic and Workplace Skills List

Unit 1: Discrete Semiconductor Devices and Circuits (cont.)

Task	Skill group	Subskill	Description
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
Construct and test a two-stage, direct-coupled amplifier (J.S. 13)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
Construct and test a Darlington pair amplifier (J.S. 14)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 1: Discrete Semiconductor Devices and Circuits (cont.)			
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a Hartley oscillator (J.S. 15)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
		Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 1: Discrete Semiconductor Devices and Circuits (cont.)			
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Test and replace silicon-controlled rectifiers (J.S. 16)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
		Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 1: Discrete Semiconductor Devices and Circuits (cont.)			
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Troubleshoot discrete solid-state device circuits (J.S. 17)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
		Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment, including computers and other technologies.

Related Academic and Workplace Skills List

Unit 2: Linear Integrated Devices and Circuits

Task	Skill group	Subskill	Description
Calculate the closed-loop gain for an inverting and a noninverting amplifier (A.S. 1)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
		Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results.
		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
Calculate the output voltage of a DC summing amplifier (A.S. 2)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 2: Linear Integrated Devices and Circuits (cont.)			
Determine specifications for commercially available op-amps (A.S. 3)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
Construct and test an inverting amplifier (J.S. 1)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Interpretation	Selecting and analyzing information and communicating the results to others.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 2: Linear Integrated Devices and Circuits (cont.)			
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a noninverting amplifier (J.S. 2)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a differential amplifier (J.S. 3)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
		Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results.
		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.

Related Academic and Workplace Skills List

Unit 2: Linear Integrated Devices and Circuits (cont.)

Task	Skill group	Subskill	Description
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a DC summing amplifier (J.S. 4)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Listening	Receiving, interpreting, and responding to verbal messages and other cues.
		Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Interpretation	Selecting and analyzing information and communicating the results to others.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 2: Linear Integrated Devices and Circuits (cont.)			
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a Hartley oscillator using an op-amp. (J.S. 5)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
		Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a low-pass active filter. (J.S. 6)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 2: Linear Integrated Devices and Circuits (cont.)			
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
		Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a timer circuit. (J.S. 7)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
		Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.

Task	Skill group	Subskill	Description
Unit 2: Linear Integrated Devices and Circuits (cont.)			
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Troubleshoot linear circuits. (J.S. 8)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
		Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
		Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results.
		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 2: Linear Integrated Devices and Circuits (cont.)			
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment, including computers and other technologies.
Unit 3: Power Supplies			
Calculate average voltages. (A.S. 1)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
Calculate rms values. (A.S. 2)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.

Related Academic and Workplace Skills List

Unit 3: Power Supplies (cont.)

Task	Skill group	Subskill	Description
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
Calculate ripple factors and percent regulation. (A.S. 3)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a nigh level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
		Interpretation	Selecting and analyzing information and communicating the results to others.
Construct and test a voltage-doubler circuit. (J.S. 1)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 3: Power Supplies (cont.)			
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a capacitor filter circuit. (J.S. 2)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.

Related Academic and Workplace Skills List

Unit 3: Power Supplies (cont.)

Task	Skill group	Subskill	Description
Construct and test a Pi-section filter circuit. (J.S. 3)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Construct and test a zener regulator. (J.S. 4)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 3: Power Supplies (cont.)			
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
Troubleshoot power supplies. (J.S. 5)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
		Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
		Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results.
		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
	Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
		Self-esteem	Developing self-confidence and maintaining a positive view of self.
		Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently.

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Description
Unit 3: Power Supplies (cont.)			
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
		Application	Demonstrating proper procedures for setting up and operating equipment.
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment, including computers and other technologies.

Correlation to Electronics Industries Foundation Skills List

Note: The Electronic Industries Foundation and its parent organization, the Electronic Industries Association, have coordinated the development of a skills list for the entry-level electronics technicians. The skills are defined in *Measurement Criteria for Entry-Level Electronics Technician Skills*, a supplement to the skills standard publication *Raising the Standard—Electronics Technician Skills for Today and Tomorrow*. Skills are defined in five areas: additional skills (communications, electromechanics, LASER applications), desirable behavior and work habits, basic and practical skills (reading, math, physics, technical literacy, etc.), test equipment and tools skills, and technical skills. In recognition of the relevance of this extensive task analysis, MAVCC has attempted to address all of the EIA/EIF technical skills in the development of the *General Electronics Technician Series*. The following table lists the EIA/EIF technical skills as of the time of publication and shows at least one example of how that skill is addressed in these instructional materials. This correlation represents the opinions of the development team in interpreting the EIA/EIF skills and is not intended to imply agreement or endorsement by the Electronic Industries Foundation. Instructors and administrators wanting more information about the EIA/EIF skills list may contact the foundation directly at the following address:

919 18th Street, NW, Suite 900
Washington, DC 20006

Note: This table lists objectives for all three books in the *General Electronics Technician* series and may not reflect the latest revisions to the other two volumes. Users should check the current edition of each work to get the most accurate listing.

Skill Code	Skill Description	Applicable Publication	Unit Number	Objective(s)
A.01	Demonstrate an understanding of proper safety techniques for all types of circuits and components	Basic	2	22-35
A.02	Demonstrate an understanding of and comply with relevant OSHA safety standards	Basic	2	27-42
A.03	Demonstrate an understanding of proper troubleshooting techniques	Basic	3	21, 23
A.04	Demonstrate an understanding of basic assembly skills using hand and power tools	Basic	3	24-38
A.05	Demonstrate an understanding of acceptable soldering/desoldering techniques, including through-hole and surface mount devices	Basic	3	31, 33, 37-42
A.06	Demonstrate an understanding of proper solderless connections	Basic	3	6, 7, 26-29, 32
A.07	Demonstrate an understanding of the use of data books and cross reference/technical manuals to specify and requisition electronic components	Basic Semiconductors	3 1 2	22 49 53
A.08	Demonstrate an understanding of the interpretation and creation of electronic schematics, technical drawings and flow diagrams	Basic	1	16, 30, 37 53

Correlation to Electronics Industries Foundation Skills List

A 09	Demonstrate an understanding of design curves, table, graphs, and recording of data	Semiconductors	1	52, 58, 66
A 10	Demonstrate an understanding of color codes and other component descriptors	Basic Semiconductors	4 2	18, 19, 32 4-7
A 11	Demonstrate an understanding of site electrical and environmental survey	Basic	2	Supplements 12 and 13
A 12	Demonstrate the use of listening skills or assistive devices to assess signs and symptoms of malfunctions	Basic	3	21
B 01	Demonstrate an understanding of sources of electricity in DC circuits	Basic	1	6
B 02	Demonstrate an understanding of principles and operation of batteries	Basic	4	5
B 03	Demonstrate an understanding of the meaning of and relationships among and between voltage, current resistance and power in DC	Basic	1 4	7, 8 33-47, 49-54
B 04	Demonstrate an understanding of the measurement of resistance of conductors and insulators and the computation of conductance	Basic	1 3	5, 46 5
B 05	Demonstrate an understanding of application of Ohm's Law to series, parallel and series-parallel circuits	Basic	1	9
B 06	Demonstrate an understanding of magnetic properties of circuits and devices	Basic	1	38-44
B 07	Demonstrate an understanding of the physical, electrical, characteristics of capacitors and inductors	Basic	5	18-45
B 08	Understand principles and operations of DC series circuits	Basic	1 4	18, 19 33-37
B 09	Fabricate and demonstrate DC series circuits	Basic	2 4	47 47, 28
B 10	Troubleshoot and repair DC series circuits	Basic	4	65
B 11	Understand principles and operations of DC parallel circuits	Basic	1 4	20, 21 38-40
B 12	Fabricate and demonstrate the DC parallel circuits	Basic	2	47
B 13	Troubleshoot and repair parallel circuits	Basic	4	66
B 14	Understand the principles and operations of DC series-parallel and bridge circuits	Basic	1 4	22, 23 30, 31, 41-45
B 15	Fabricate and demonstrate DC series-parallel and bridge circuits	Basic	4	51-53
B 16	Troubleshoot and repair series-parallel and bridge circuits	Basic	4	66
B 17	Understand the principles and operations of Wheatstone Bridge	Basic	4	30, 31, 53
B 18	Understand the principles and operations of DC voltage divider circuits (loaded and unloaded)	Basic	4	28, 29
B 19	Fabricate and demonstrate the DC voltage divider circuits (loaded and unloaded)	Basic	4	50
B 20	Troubleshoot and repair DC voltage divider circuits (loaded and unloaded)	Basic	4	66

Correlation to Electronics Industries Foundation Skills List

B.21	Understand principles and operations of DC RC and RL circuits	Basic	4	18-26, 33-41, 59-71
B.22	Fabricate and demonstrate DC RC and RL circuits	Basic	5	81, 84
B.23	Troubleshoot and repair DC RC and RL circuits	Basic	5	66
B.24	Demonstrate an understanding of measurement of power in DC circuits	Basic	4	37, 40, 45
C.01	Demonstrate an understanding of sources of electricity in AC circuits	Basic	1 5	6 8-12
C.02	Demonstrate an understanding of the properties of an AC signal	Basic	5	4-6
C.03	Demonstrate an understanding of the principles of operation and characteristics of sinusoidal and non-sinusoidal wave forms	Basic	5	5
C.04	Demonstrate an understanding of basic motor/generator theory and operation	Basic	5	12, 13
C.05	Demonstrate an understanding of measurement of power in AC circuits	Basic	5	56, 74
C.06	Demonstrate an understanding of the principle and operation of various power conditioning: (isolation transformers, surge suppressors, uninterruptable power systems)	Basic	5	47, 48
C.07	Demonstrate an understanding of the principle and operation of safety grounding systems: (lightning arresters, ground fault interrupters, etc.)	Basic	1	14-16
C.08	Understand principles and operations of AC capacitive circuits	Basic	5	27-41, 64-68
C.09	Fabricate and demonstrate AC capacitive circuits	Basic	5	84, 87
C.10	Troubleshoot and repair AC capacitive circuits	Basic	5	90
C.11	Understand principles and operations of AC inductive circuits	Basic	5	18-26, 59-63
C.12	Fabricate and demonstrate AC inductive circuits	Basic	5	80, 81
C.13	Troubleshoot and repair AC inductive circuits	Basic	5	90
C.14	Understand principles and operations of AC circuits using transformers	Basic	5	14-17, 74, 75
C.15	Demonstrate an understanding of impedance matching theory	Basic	5	53
C.16	Fabricate and demonstrate AC circuits using transformers	Basic	5	78, 79
C.17	Troubleshoot and repair AC circuits using transformers	Basic	5	90
C.18	Understand principles and operations of AC differentiator and integrator circuits (determine RC and RL time constants)	Basic	5	49, 66
C.19	Fabricate and demonstrate the operation of differentiators and integrators			

Correlation to Electronics Industries Foundation Skills List

C 20	Troubleshoot and repair AC differentiator and integrator circuits	Basic	5	90
C 21	Understand principles and operations of AC series and parallel resonant circuits	Basic	5	43, 45, 62, 73
C 22	Fabricate and demonstrate AC series and parallel resonant circuits	Basic	5	88, 89
C 23	Troubleshoot and repair AC series and parallel resonant circuits	Basic	5	90
C 24	Understand principles and operations of AC RC, RL, and RLC circuits	Basic	5	24-45, 59-73
C 25	Fabricate and demonstrate AC RC, RL and RLC circuits	Basic	5	81, 87-89
C 26	Troubleshoot and repair AC RC, RL and RLC circuits	Basic	5	90
C 27	Understand principles and operations of AC frequency selective filter circuits	Basic	5	50-52
C 28	Fabricate and demonstrate the operation of frequency selective filter circuits	Semiconductors	2	59
C 29	Troubleshoot and repair AC frequency selective filter circuits	Basic	5	90
C 30	Understand principles and operations of AC polyphase circuits	Basic	5	16, 74, 75
C 31	Understand principles and operations of AC phase locked loop circuits	Semiconductors	2	32
C 32	Troubleshoot and repair AC phase locked loop circuits	Semiconductors	2	61
D 01	Demonstrate an understanding of the properties of semiconductor materials	Semiconductors	1	4-6
D 02	Demonstrate an understanding of PN junctions	Semiconductors	1	6
D 03	Demonstrate an understanding of bipolar transistors	Semiconductors	1	15-23
D 04	Demonstrate an understanding of Field Effect Transistors	Semiconductors	1	24-31
D 05	Demonstrate an understanding of special diodes and transistors	Semiconductors	1	7-31, 41
D 06	Understand principles and operations of diode circuits	Semiconductors	1	9
D 07	Fabricate and demonstrate diode circuits	Semiconductors	1	58-61
D 08	Troubleshoot and repair diode circuits	Semiconductors	1	73
D 09	Understand principles and operations of optoelectronic circuits (gate isolators, interrupt sensors, infra-red sensors, etc.)	Semiconductors	2	49
D 10	Fabricate and demonstrate optoelectronic circuits	Semiconductors	1	61
D 11	Troubleshoot and repair optoelectronic circuits	Semiconductors	2	61
D 12	Understand principles and operations of single stage amplifiers	Semiconductors	1	34
D 13	Fabricate and demonstrate the operation of the single stage amplifiers	Semiconductors	1	67

Correlation to Electronics Industries Foundation Skills List

D 14	Troubleshoot and repair single-stage amplifiers	Semiconductors	1	73
D 15	Understand principles and operations of thyristor circuitry	Semiconductors	1	44, 45
D 16	Fabricate and demonstrate thyristor circuitry	Semiconductors	1	60, 72
D 17	Troubleshoot and repair thyristor circuitry	Semiconductors	1	73
E 01	Understand principles and operations of multistage amplifiers	Semiconductors	1	32-40, 55
E 02	Fabricate and demonstrate the operation of multistage amplifiers	Semiconductors	1	68, 69
E 03	Troubleshoot and repair multistage amplifiers	Semiconductors	1	73
E 04	Understand principles and operations of IF circuits	Semiconductors	2	41
E 05	Fabricate and demonstrate IF circuits	See MAVCC's *Electronics Communications*		
E 06	Troubleshoot and repair IF circuits	Semiconductors	2	61
E 07	Understand principles and operations of linear power supplies and filters	Semiconductors	3	2-14
E 08	Fabricate and demonstrate linear power supplies and filters	Semiconductors	3	21-24
E 09	Troubleshoot and repair linear power supplies and filters	Semiconductors	3	17, 25
E 10	Understand principles and operations of operational amplifier circuits	Semiconductors	2	16-23
E-11	Fabricate and demonstrate operational amplifier circuits	Semiconductors	2	54-60
E 12	Troubleshoot and repair operational amplifier circuits	Semiconductors	2	61
E 13	Understand principles and operations of audio power amplifiers	Semiconductors	1	35, 36, 39
E 14	Fabricate and demonstrate audio power amplifiers	Semiconductors	1	67-70
E 15	Troubleshoot and repair audio power amplifiers	Semiconductors	1	73
E 16	Understand principles and operations of regulated and switching power supply circuits	Semiconductors	3	2-16
E 17	Troubleshoot and repair regulated and switching power supply circuits	Semiconductors	3	25
E 18	Understand principles and operations of active filter circuits	Semiconductors	2	33, 34
E 19	Troubleshoot and repair active filter circuits	Semiconductors	2	61
E 20	Understand principles and operations of sinusoidal and non-sinusoidal oscillator circuits	Semiconductors	2	27-31, 58
E 21	Troubleshoot and repair sinusoidal and non-sinusoidal oscillator circuits	Semiconductors	2	61
E 22	Understand principles and operations of fiber optic circuits using photodiodes or LASERS	Semiconductors	2	45, 46

Correlation to Electronics Industries Foundation Skills List

E 23	Troubleshoot and repair fiber optic circuits using photodiodes or LASERS	Semiconductors	2	61
E 24	Understand principles and operations of RF circuits	Semiconductors	2	39, 40
E 25	Fabricate and demonstrate RF circuits	See MAVCC's *Electronics Communications*		
E 26	Troubleshoot and repair RF circuits	Semiconductors	2	61
E 27	Understand principles and operations of signal modulation systems (AM, FM, Stereo)	Semiconductors	2	42
E 28	Troubleshoot and repair signal modulation systems (AM, FM, Stereo)	Semiconductors	2	61
E 29	Demonstrate an understanding of motor phase shift control circuits	Semiconductors	2	32, 36, 47, 48
E 30	Understand principles and operations of microwave circuits	Semiconductors	2	43, 44
F 01	Demonstrate an understanding of the characteristics of integrated circuit (IC) logic families	Digital	1	2
F 02	Demonstrate an understanding of minimizing logic circuits using Boolean operations	Digital	1	33
F 03	Understand principles and operations of linear integrated circuits	Semiconductors	2	2-50
F 04	Troubleshoot and repair linear integrated circuits	Semiconductors	2	61
F 05	Understand principles and operations of types of logic gates	Digital	1	3, 4
F 06	Fabricate and demonstrate types of logic gates	Digital	1	34-38
F 07	Troubleshoot and repair types of logic gate circuits	Digital	1	46
F 08	Understand principles and operations of combinational logic circuits	Digital	1	20
F 09	Fabricate and demonstrate combinational logic circuits	Digital	1	39-45
F 10	Troubleshoot and repair combinational logic circuits	Digital	1	46
F 11	Understand principles and operations of types of flip-flop circuits	Digital	1	6, 7
F 12	Fabricate and demonstrate the operation of flip-flop circuits	Digital	1	40
F 13	Troubleshoot and repair flip-flop circuits	Digital	1	46
F 14	Understand principles and operations of types of registers and counters	Digital	1	8-11
F 15	Fabricate and demonstrate types of registers and counters	Digital	1	39, 41
F 16	Troubleshoot and repair types of registers and counters	Digital	1	46
F 17	Understand principles and operations of clock and timing circuits	Digital	1	12, 13
F 18	Fabricate and demonstrate clock and timing circuits	Digital	1	45

Correlation to Electronics Industries Foundation Skills List

F 19	Troubleshoot and repair clock and timing circuits	Digital	1	46
F 20	Understand principles and operations of types of arithmetic-logic circuits	Digital	1	14
F 21	Troubleshoot and repair types of arithmetic-logic circuits	Digital	1	46
F 22	Understand principles and operations of types of multiplexer and de-multiplexer circuits	Digital	1	15, 16
F 23	Troubleshoot and repair multiplexer and de-multiplexer circuits	Digital	1	46
F 24	Understand principles and operations of types of digital to analog and analog to digital circuits	Digital	1	43, 44
F 25	Troubleshoot and repair types of digital-to-analog and analog-to-digital circuits	Digital	1	46
F 26	Understand principles and operations of types of digital display circuits	Digital	1	2, 44
F 27	Troubleshoot and repair types of digital display circuits	Digital	1	46
F 28	Understand principles and operations of power distribution and noise problems	Digital	1	19
F 29	Troubleshoot and repair power distribution and noise problems	Digital	1	46
F 30	Understand principles and operations of types of digital encoders and decoders	Digital	1	18
F 31	Troubleshoot and repair types of digital encoders and decoders	Digital	1	46
F 32	Understand principles and operations of digital display devices	Digital	1	20, 21
F 33	Troubleshoot and repair digital display devices	Digital	1	46
G 01	Demonstrate an understanding of microprocessor interfaces	Digital	2	3
G 02	Troubleshoot and repair microprocessor interfaces	Digital	2	26
G 03	Demonstrate an understanding of essential microprocessor components	Digital	2	3
G 04	Demonstrate an understanding of microprocessor BUS concepts	Digital	2	9-12
G 05	Demonstrate an understanding of microprocessor components and terminology	Digital	2	1, 2
G 06	Understand principles and operation of types of microprocessor memory circuits	Digital	2	8
G 07	Troubleshoot and repair types of microprocessor memory circuits	Digital	2	26
G 08	Understand principles and operations of microprocessor machine code and instruction sets	Digital	2	16-18
H 01	Demonstrate an understanding of microcomputer operating systems	Digital	2	20
H 02	Demonstrate an understanding of essential microcomputer components	Digital	2	15

Correlation to Electronics Industries Foundation Skills List

H.03	Demonstrate an understanding of microcomputer peripherals	Digital	2	21
H.04	Setup and configure a microcomputer using available operating systems and software packages peripherals	Digital	2	25
H.05	Troubleshoot and replace microcomputer peripherals	Digital	2	26

Discrete Semiconductor Devices and Circuits
Unit 1

Suggested Activities

Instructional Plan

Preparation

- Review unit and plan presentation. Study the specific objectives to determine the order in which you will present the objectives.

  Review the unit introduction and teaching suggestions included in the delivery and application section below, and plan classroom activities. Also note the suggestions for media and supplemental materials.

  Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.

- Obtain films, videotapes, and other media to supplement instruction of this unit. See ordering information in the suggested resources section.

- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only and should be used with objectives as indicated below.

  TM 1—P-N Junction (Objective 5)
  TM 2—Biasing Effects on the P-N Junction (Objective 6)
  TM 3—P-N Junction Diode Characteristic Curve (Objective 7)
  TM 4—Zener Diode Characteristics (Objective 8)
  TM 5—Tunnel Diode Characteristics (Objective 8)
  TM 6—Various Transistor Cases (Objective 9)
  TM 7—PNP Transistor Majority Current Carriers (Objective 15)
  TM 8—Transistor Block Diagrams and Schematics (Objective 15)
  TM 9—Comparison of Transistor Circuit Configurations (Objectives 19-21)
  TM 10—Correctly Biased Transistors (Objectives 22 and 23)
  TM 11— Electron Flow in NPN and PNP Transistor Circuits (Objectives 22 and 23)
  TM 12—Transistor Load Line (Objective 23)
  TM 13—Junction Field-Effect Transistor (Objective 24)
  TM 14—Metal Oxide Semiconductor Field-Effect Transistor (Objective 30)
  TM 15 –Single-Ended Amplifier (Objective 33)
  TM 16—Common-Base (PNP) Amplifier Circuit (Objective 33)
  TM 17—Common-Collector (NPN) Amplifier Circuit (Objective 33)
  TM 18—Common-Emitter (NPN) Amplifier Circuit (Objective 33)
  TM 19—Feedback (Objective 34)

Suggested Activities

TM 20—Load Line for a C-E Amplifier (Objective 34)
TM 21—Frequency Compensation Networks (Objective 35)
TM 22—Push-Pull Amplifier (Objective 36)
TM 23—Complementary Symmetry Amplifier (Objective 36)
TM 24—Darlington Pair (Objective 36)
TM 25—Types of Oscillators (Objective 43)
TM 26—Types of Oscillators (Continued) (Objective 43)
TM 27—Crystal-Controlled Oscillator (Objective 43)
TM 28—Thyristors (Objective 44)
TM 29—Half-Wave Rectifier Circuits (Objective 47)
TM 30—Full-Wave Rectifier Circuit (Objective 47)
TM 31—Full-Wave Bridge Rectifier Circuit (Objective 47)
TM 32—Voltage Regulation (Objective 48)
TM 33—Zener Diode Regulators (Objective 48)
TM 34—Series Regulators (Objective 48)

- Select teacher components (supplements, written test, unit evaluation form) you want to distribute to your students. Copy and prepare these components for distribution. The supplements included in this unit are designed for use with the objectives as indicated below.

  Supplement 1—Report on a Diode (Objectives 7-10)
  Supplement 2—Report on a Bipolar Junction Transistor (Objectives 15-23)
  Supplement 3—Report on a Field-Effect Transistor (Objective 24)
  Supplement 4—Report on an Insulated Gate FET (Objective 31)
  Supplement 5—Report on a Unijunction Transistor (Objective 41)
  Supplement 6—Report on a Thyristor (Objective 43)
  Supplement 7—Report on an Amplifier Application (Objectives 32-40)
  Supplement 8—Report on an Oscillator Application (Objective 20)

- Prepare classroom. Put up posters and charts and display articles and other references related to the objectives of this unit. Component manufacturers distribute posters of products, characteristic curves, schematics, and other materials that would be useful in supporting this unit. Display products spanning the history of electronics, from vacuum tubes, to discrete semiconductor components, to SSI circuits, to VLSI devices. Try to relate the circuits to each other. For example, if you can display an IC that has extensively more capabilities than displayed circuits of discrete components and early semiconductors.

Suggested Activities

Delivery and Application

Unit Introduction

- Discuss unit and specific objectives.
- Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets and job sheets. Review with students the criteria for evaluation of each of these activities.

Teaching Suggestions

The skill areas appearing in bold-face type in the teaching suggestions refer to the academic and workplace skills identified in *What Work Requires of School: A SCANS Report for America 2000* and *Workplace Basics: The Skills Employers Want*. These have been adapted by MAVCC.

- Display some vacuum tubes and early discrete components to show the progress that has been made with semiconductors in terms of size, power consumption, heat generation, etc. Show the students samples of semiconductor materials and doping elements, such as silicon, germanium, arsenic, and boron. Tour a semiconductor manufacturing plant or university laboratory doing research on semiconductors. **(Listening; seeing things in the mind's eye; responsibility; materials and resources; career awareness)**
- As you cover each type of component, display examples of each in a variety of packages and circuits containing those components along with schematics for those circuits—using both commercial and industrial applications. Discuss the role of the subject component in the circuit. Discuss reasons for choosing that particular component and package for the specific application. Discuss troubleshooting issues and procedures for the component and the applications. As you continue through the unit, reduce the amount that you lecture and demonstrate on these subjects and shift the responsibilities to the students. Use data sheets and the supplements to have the students make reports to the class about the latest advances in semiconductor devices and to expand the class's knowledge base about the devices being studied. **(Listening; reading; writing; speaking; acquiring, organizing, interpreting, and processing information; science; applying technology; adapting to the organization's goals and values)**

Suggested Activities

- As you cover the semiconductor applications in this unit, display circuits, schematics, troubleshooting charts, and other resources to supplement the discussions. Demonstrate actual applications and relate them to larger systems. Review the interrelationship of the applications, such as amplifiers and oscillators. Use the supplements to have the students report on innovations in such applications. Introduce the fact that these components and circuits are often available as ICs, but keep the discussion of ICs at a level that will not confuse your students. One approach is to discuss the Darlington connection, show a Darlington transistor, and then show an IC that incorporates Darlington pairs. Get the students to think about the electronics in their everyday lives and speculate as to the use of amplifiers, oscillators, rectifiers, etc. in those devices. **(Listening; reading; writing; speaking; acquiring, organizing, interpreting, and processing information; science; applying technology; adapting to the organization's goals and values; system interrelationships)**

- Point out variations in component symbols, such as transistors enclosed in circles and those not, and different ways of showing inputs, outputs, common grounds, etc. Help the students understand how to interpret the way data is presented in specification tables, characteristic curves, waveform illustrations, etc. Use such technical data and demonstrations to introduce concepts such as noise, signal-to-noise ratio, crossover distortion, etc.—which are covered in more detail in the next unit. Also relate oscilloscope displays and equipment performance (such as the sound from speakers and graphic analyzer displays) to distortion and to concepts that appear on data sheets, such as breakover voltage, PIV, and breakdown voltage. **(Listening; reasoning; applying technology; seeing things with the mind's eye)**

- The assignment sheets in this unit lend themselves especially well to be supplemented with the use of actual components and systems. For example, the concept of gain can become more concrete for the students if they can calculate a gain of 6 dB and then hear the effects of that gain. How small of a decibel increase can they distinguish audibly? Use actual circuits to supplement the drawings in the assignment sheets on common-emitter amplifiers, oscillators, and transistor circuits. Take the time to do the calculations represented on a load line for one example so that the students will see that the numbers are not just arbitrary and that the load line is another tool to use. **(Listening; seeing things in the mind's eye; adapting to the organization's goals and values; problem-solving; arithmetic/mathematics; reasoning; interpreting information)**

Suggested Activities

Evaluation

- Discuss with students the use of the Unit Evaluation Form. Explain the rating scale that will be used for student evaluation.
- Copy written test and give to students as pretest. Record pretest score on the Unit Evaluation Form.
- Evaluate assignment sheets. See the evaluation criteria listed at the top of each assignment sheet and the component "Answers to Assignment Sheets."
- Evaluate job sheets. See the evaluation criteria listed at the top of each job sheet.
- Give and evaluate written test.
- Compile written-test, assignment-sheet, and job sheet scores on the Unit Evaluation Form. Include any additional assignments.
- Measure competency gains by comparing written pretest scores with posttest scores.
- Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.
- Reteach and retest as required.

Instructions for Evaluating Student Performance

- When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

  Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Suggested Activities

Option A

1 — Skilled—Can perform job with no additional training.
2 — Moderately skilled—Has performed job during training program; limited additional training may be required.
3 — Limited skill—Has performed job during training program; additional training is required to develop skill.
4 — Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Suggested Resources

Resources Used in Developing This Unit

- *Basic Electronics.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1987.
- *Communications Electronics.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1988.
- Davidson, Homer L. *Electronic Troubleshooting and Repair Handbook.* New York: McGraw-Hill, 1995.
- Davidson, Homer L. *Troubleshooting and Repairing Compact Disc Players.* 2nd Ed. New York, New York: TAB Books, 1994.
- *General Electronics Technician.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1987.
- *Graphic Symbols for Electrical and Electronics Diagrams.* New York: Institute of Electrical and Electronics Engineers, Inc., 1975.
- *Home Electronics.* Alexandria, Virginia: Time-Life Books, 1988.
- McMenamin, J. Michael. *Applied Electronic Devices and Analog ICs.* Albany, New York: Delmar Publishing, Inc., 1995.
- Newby, Bruce. *Electronic Signal Conditioning.* Oxford, England: Butterworth-Heinemann Ltd., 1994.
- Pallás-Areny, Ramón and John G. Webster. *Sensors and Signal Conditioning.* New York: John Wiley & Sons, Inc., 1991.

- Roehrig, Guido and Ulrich Schueller. *Upgrading and Maintaining Your PC*. Grand Rapids, Michigan: Abacus, 1991.
- Schuler, Charles A. *Electronics Principles and Applications*. 4th edition. New York: Glencoe Division, Macmillan/McGraw-Hill School Publishing Company, 1994.
- Simpson, Colin D. *Principles of Electronics*. Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1996.
- Villanucci, Robert S., Alexander W. Avtgis, and William F. Megow. *Electronics Techniques: Shop Practices and Construction*. 5th Edition. Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1996.

Supplemental Resources

Print Media

- Data sheets for applicable semiconductor devices. Available from manufacturers and in handbooks.
- Schematics for circuits discussed in conjunction with this unit. Available from equipment manufacturers.

Non-print Media

- *Advanced Solid-State Electronics*. Discusses transistors, ICs, differentiators, integrators, and other topics from this and the next unit. Be sure to get the latest version of this program. Available from: Instructional Society of America; 67 Alexander Drive; P.O. Box 12277; Research Triangle Park, NC 27709; 800-334-6391.
- *Amplifier Applications*. Covers transistor amplifiers with an emphasis on Classes A, B, and C. Available from: Tel-A-Train; P.O. Box 4752; Chattanooga, TN 37405; 800-266-0113.
- *Bipolar Transistors*. This 1992 program covers the design and operation of bipolar transistors, amplifiers, but also discusses logic gates. Available from: American Association for Vocational Instructional Materials; 745 Gaines School Road; Athens, GA 30605; 800-228-4689.
- *Bipolar Transistors as Switches*. Covers this basic role of bipolar transistors. Released in 1989. Available from: Tel-A-Train; P.O. Box 4752; Chattanooga, TN 37405; 800-266-0113.

Suggested Activities

- *The Challenge of Opto-Electronics.* A general overview of this developing technology. Available from: The Japanese Institute for Social and Economic Affairs, Charles Von Loewenfeldt, Inc., 1333 Gough St., San Francisco, CA 94109.

- *Semiconductor Principles.* Explains the characteristics of semiconductors, their manufacture, and their uses in circuits. Available from: Career Aids, Inc.; 20417 Nordhoff St., Dept. VCE; Chatsworth, CA; 91311.

- *Silicon Controlled Rectifiers.* This program concentrates on thyristors and SCRs in particular. Available from: Career Aids, Inc.; 20417 Nordhoff St., Dept. VCE; Chatsworth, CA; 91311.

- *Transistor Amplifiers.* Covers the use of transistors in amplifier circuits. Available from: NUS Training Corporation; 910 Clopper Rd.; Gaithersburg, MD 20878-1399; 800-848-1717.

- *Transistor Oscillators.* Introduces the concept of oscillators and how they function. Available from: NUS Training Corporation; 910 Clopper Rd.; Gaithersburg, MD 20878-1399; 800-848-1717.

- *Transistor Principles.* This program discusses the basics of transistor functioning and types of transistors. Part of a series with the previous two programs listed. Available from: NUS Training Corporation; 910 Clopper Rd.; Gaithersburg, MD 20878-1399; 800-848-1717.

- *Transistors.* This series includes two programs, the first of which covers the basics of P-N junctions and bipolar transistors. The second program concentrates on other types of transistors and applications. Available from: Career Aids, Inc.; 20417 Nordhoff St., Dept. VCE; Chatsworth, CA; 91311.

Discrete Semiconductor Devices and Circuits
Unit 1

Answers to Assignment Sheets

Assignment Sheet 1— Use Resource Materials to Determine Pin Configurations for Common Types of Semiconductor Devices

1. a. Anode
   b. Cathode
2. a. Emitter
   b. Collector
   c. Base
3. a. Anode
   b. Cathode
4. a. Gate
   b. Anode
   c. Cathode
5. a. Anode
   b. Cathode
6. a. Emitter
   b. Base
   c. Collector
7. a. Drain
   b. Gate
   c. Source
8. a. Anode
   b. Cathode
9. a. Emitter
   b. Base
   c. Collector
10. a. Emitter
    b. Base 1
    c. Base 2

Assignment Sheet 2— Interpret Functions of Electronic Circuits Constructed from Discrete Semiconductor Components

1. a. 2
   b. 2
   c. 1
   d. 2
2. a. 1
   b. 4
   c. 1
   d. 2
3. a. 4
   b. 1
   c. 3
   d. 4

Answers to Assignment Sheets

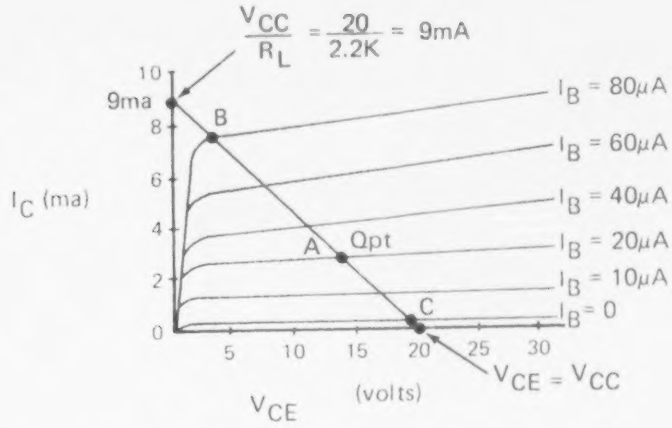
4.	a.	2
	b.	1
	c.	3
	d.	2
5.	a.	2
	b.	3
	c.	4
	d.	4
6.	a.	4
	b.	2
	c.	3
	d.	4
7.	a.	2
	b.	3
	c.	2
	d.	1
8.	a.	2
	b.	3
	c.	3
	d.	3
9.	a.	4
	b.	1
	c.	1
	d.	4
10.	a.	2
	b.	1
	c.	2
	d.	3

Assignment Sheet 3— Label the Parts of a Transistor Circuit

1.	NPN	
2.	a.	2
	b.	1
	c.	3
3.	a.	2
	b.	1
4.	b	
5.	a	

Answers to Assignment Sheets

Assignment Sheet 4— Construct a Load Line for a Common-Emitter Amplifier Circuit



1. 7.5 mA, 4 V
2. 2.5 mA, 14 V
3. 0.3 mA, 19 V

Assignment Sheet 5— Calculate the Gain of Amplifier Circuits

1. 30
2. 7.5
3. 10
4. 6.5
5. 45
6. 30
7. 20
8. 12
9. 30
10. 50

Assignment Sheet 6— Compute Voltage, Current, and Power Stage Gain in Decibels

1. 36 dB
2. 20 dB
3. 9 dB
4. 7 dB
5. 14 dB
6. 32 dB
7. 13 dB
8. 16 dB
9. 38 dB
10. 12 watts

Answers to Assignment Sheets

Assignment Sheet 7— Calculate the Overall Gain of Multistage Amplifiers

1. 55.5 dB
2. 73.8 dB
3. 990
4. 5000
5. 30 dB

Assignment Sheet 8—Identify Types of Transistors Used in Oscillators

1. a
2. d
3. c
4. a
5. c
6. a
7. f
8. a
9. c
10. f
11. a
12. a
13. 1, 5, 6, 9
14. 3, 11
15. 4
16. 2, 6, 8

Discrete Semiconductor Devices and Circuits
Unit 1

Answers to Written Test

1.	a.	10	f.	7	k.	1	p.	9
	b.	8	g.	5	l.	11	q.	13
	c.	6	h.	17	m.	15	r.	12
	d.	14	i.	18	n.	2	s.	3
	e.	4	j.	16	o.	19		

2. (Answer should include two applications for each device)

a. Diodes
- Rectifiers
- Voltage regulators
- Signal blocking

b. Bipolar transistors
- Amplifiers
- Oscillators
- Switches

c. Field-effect transistors
- Amplifiers
- Oscillators
- Switches

d. Unijunction transistors
- Timers
- Oscillators
- Triggers

e. Thyristors
- Switches
- Triggers
- Oscillators

3. a. F
b. R

4. a. Conductivity
b. N-type
c. P-type
d. Electrons
e. Holes
f. N-type
g. P-type

5. a. N
b. P

Answers to Written Test

6. a. Crystals
b. N-type
c. Depletion region
d. Diode, diode
e. Insulator
f. Potential
g. Forward
h. Reverse
i. Leakage

7. a. Anode, cathode
b. Cathode to anode
c. Virtually no
d. Increases
e. Maximum current
f. Virtually no
g. Minority
h. Peak inverse voltage

8.

a.	4	d.	6	g.	8	j.	7
b.	9	e.	1	h.	12	k.	3
c.	2	f.	10	i.	5	l.	11

9. (Answer should include at least one of each application listed with each device; instructor may choose to accept additional applications that may have been discussed in class)

a. Diode—Rectification, blocking, detecting, steering
b. Zener (avalanche) diode—Regulation, reference, clipping
c. Tunnel diode—UHF converter, logic circuits, microwave circuits, level sensing
d. Backward diode—Microwave mixers, low-power oscillators
e. Photodiode—Fiber optic circuits, light sensors
f. PIN diode—Variable resistor, microwave circuits
g. Light-emitting diode—Indicators, displays
h. Schottky (hot carrier) diode—Switching, RF mixer, harmonic generation
i. IMPATT (impact avalanche transit time) diode—RF power generator, microwave circuits
j. Varactor (varicap) diode—Amplifiers, oscillators, voltage multipliers
k. Varistor—Voltage divider, surge suppresser
l. Thyrector (bidirectional diode)—Transient voltage suppression

10.

a.	2, 3	d.	5	g.	1	j.	12
b.	8	e.	7	h.	11	k.	9
c.	10	f.	6	i.	4		

11. a. Heat
b. Shock
c. Excessive current

Answers to Written Test

12. a. NPN
    b. P-channel
    c. P-type
    d. N-type
    e. PNP
    f. N-channel
    g. N-channel
    h. PNP
    i. P-type
    j. NPN
    k. N-type
    l. P-channel

13. a. 13
    b. 6
    c. 9
    d. 11
    e. 10
    f. 8
    g. 14
    h. 5
    i. 3
    j. 12
    k. 4
    l. 1
    m. 7
    n. 2

14. a. 3
    b. 6
    c. 4
    d. 5
    e. 1
    f. 10
    g. 2
    h. 8
    i. 11
    j. 9
    k. 7

15. a. Leads
    b. Semiconductor
    c. Base
    d. Majority
    e. Bipolar
    f. Collector, base
    g. Current, off
    h. Reverse, forward
    i. High, low
    j. $I_B + I_C$
    k. Current, current
    l. Base, collector
    m. Common-base, common-emitter, common-collector
    n. Cases

16. a. Free electrons flow from the emitter to the base and from the base to the collector.
    b. Approximately 5 percent of the electrons come from the emitter, while the rest come from the base.
    c. The base is narrow and lightly doped.

17. a. Free electrons flow from the collector to the base and from the base to the emitter.
    b. Because the emitter-base region is low resistance, a small input signal results in maximum current flow.
    c. The base is narrow and lightly doped.

18. a. C
    b. B
    c. E
    d. B
    e. E
    f. C
    g. C
    h. E
    i. B
    j. B
    k. E
    l. B

19. a. Bipolar
    b. High
    c. Low

Answers to Written Test

d. Medium
e. Low
f. High
g. In-phase

20. a. Bipolar
b. Low
c. High
d. Low
e. High
f. Low
g. In-phase

21. a. Bipolar
b. High
c. High
d. High
e. Medium
f. Medium
g. Out-of-phase

22. To achieve maximum output voltage swing without distortion or to provide a specific output voltage at the collector

23. a. 1
b. 3
c. 4
d. 2

24. a. Gate, source, drain
b. Channel
c. N-channel, P-channel
d. Voltage, on
e. Voltage divider
f. Negative
g. Narrower
h. Pinch-off
i. Pinch-off
j. Greater, lower
k. Transconductance
l. Drain
m. Common-gate, common-source, common-drain
n. Cases

25. a. FET
b. High
c. Low
d. Medium

Answers to Written Test

e. Low
f. High
g. In-phase

26. a. FET
b. Low
c. High
d. Low
e. High
f. Low
g. In-phase

27. a. FET
b. High
c. High
d. High
e. High
f. Medium to high
g. Out-of-phase

28. To achieve maximum stability in the operating point while preventing operation from going beyond the cutoff

29. a. 3
b. 2
c. 1

30. a. Gate
b. Two
c. Isolated from
d. Enhancement, depletion
e. Off
f. On
g. Increases
h. Negative, positive

31. a, b, d, f, g

32. a. Infinite gain
b. No output resistance
c. Infinite input resistance

33. b, c, e, f, g, h

34. a. The purpose of an amplifier is to provide gain—that is, the output signal will be stronger than the input signal.

b. While various devices (such as transformers) may increase the current or voltage of an output signal, they usually do so through the reduction of another characteristic, so that amplifiers are the only devices capable of simultaneous increases in voltage, current, and power.

c. Gain or amplification is expressed as a ratio between output signal and the input signal and can be expressed by formulas such as

$A_V = \frac{V_{out}}{V_{in}}$ for voltage gain,

$A_I = \frac{I_{out}}{I_{in}}$ for current gain, and

$A_P = \frac{P_{out}}{P_{in}}$ for power gain.

d. It is possible for the input signal to exceed the gain capabilities of the amplifier, leading to a condition where the full output waveform cannot be produced and the resulting waveform is *distorted* or *clipped*.

e. The upper limit of the input signal is referred to as the *saturation limit*.

f. The upper limit of the output signal is called the *cutoff limit*.

g. An amplifier can be tuned to a certain frequency or range of frequencies through the use of circuits that are resonant at those frequencies.

h. The power transfer of an amplifier can be maximized through impedance matching.

i. Signals can be transferred from one amplifier to another by coupling the amplifiers to *multistage* or *cascaded* amplifiers.

j. Amplifier circuits can be constructed to develop a signal that will interact with the input signal to provide *feedback*.

k. If the feedback reduces the amplifier gain, it is referred to as *negative feedback*, but negative feedback can be used to improve other properties of the amplifier, such as increasing its bandwidth, change its impedances, or make the amplifier quieter.

l. The point at which an amplifier's gain drops 3 decibels below its best gain is called its *break frequency*.

m. Amplifier performance is generally represented in graphs called *load lines* that show amplifier operational status at various combinations of voltage and current.

35. a. Saturation
b. Saturation
c. Last
d. Low
e. Efficiency

Answers to Written Test

36. a. Single-ended
    b. Darlington pair
    c. Push-pull
    d. Complementary
    e. Multistage

37. a. Saturation—Condition in which a further increase in voltage will not lead to a significant increase in current
    b. Cutoff—Condition in which a biased device will not support current flow
    c. Active—Condition of device operation in which current flow is a function of the device's controlling current or voltage

38. a. 4
    b. 3
    c. 2
    d. 5
    e. 1

39. a. D
    b. A
    c. AB
    d. B
    e. C

40. a. 4
    b. 1
    c. 5
    d. 2
    e. 3

41. a. Emitter, base 1, base 2
    b. N-type
    c. P-type
    d. Negative
    e. 1, 1
    f. On
    g. Holding
    h. Voltage, off
    i. Valley
    j. Increase
    k. Resistances
    l. Oscillators
    m. Are not

42. a. Frequency determining network—Sets the oscillation frequency
    b. Amplifier stage—Replaces circuit losses

Answers to Written Test

c. Positive feedback circuit—Supplies a regenerative signal back to the frequency determining components to maintain oscillations
d. DC power supply—Supplies the frequency determining network and amplifier with electrical energy
e. Self-starting oscillator device—Generates the oscillations

43. a. 3
b. 1
c. 2

44. a. 5
b. 1
c. 3
d. 6
e. 7
f. 4
g. 2
h. 8

45. a. CSCR
b. SCR
c. Bilateral switch
d. LASCR
e. Diac
f. Unilateral switch
g. SCS
h. CSCR
i. Unilateral switch
j. Diac
k. SCR
l. Triac
m. Triac
n. Bilateral switch
o. LASCR
p. SCS

46. a. Half-wave
b. Full-wave

47. a. 3
b. 2
c. 1
d. 4
e. 5

48. a. Zener diode shunt regulator
b. Transistor shunt regulator
c. Transistor series regulator
d. Thyristor regulator

Discrete Semiconductor Devices and Circuits
Unit 1

Written Test

Name ______________________ Date __________ Score __________

1. Match terms associated with semiconductor devices and circuits to their correct definitions. Write the corresponding numbers on the blanks provided.

_____a. Circuit that consists of one set of components that is electrically identical to a circuit composed of a different set of components

_____b. An impurity added to a semiconductor to create N-type material that is rich in electrons that can be donated to other atoms

_____c. Signal distortion characterized by loss of amplitude usually as a result of improper biasing or excessive input signal strength

_____d. Semiconductor material that has been doped with a donor impurity so that it conducts current with electrons

_____e. Amount of reverse-biased voltage required to suddenly increase reverse current flow

_____f. Condition of a semiconductor crystal having few available current carriers

_____g. Negative electrode of an electrical or electronic device

_____h. Process of changing AC to DC

_____i. Substance whose electrical characteristics with regard to current flow lie between those of conductors and insulators

_____j. Semiconductor material that has been doped with an acceptor impurity so that it conducts current with holes

_____k. An impurity added to a semiconductor to create P-type material that is rich in holes that accept electrons

1. Acceptor
2. Ambient temperature
3. Anode
4. Breakdown voltage
5. Cathode
6. Clipping
7. Depletion
8. Donor
9. Doping
10. Electrical equivalent
11. Junction
12. Majority carrier
13. Minority carrier
14. N-type material
15. Optoelectronic device
16. P-type material
17. Rectification
18. Semiconductor
19. Surge

Written Test

_______l. Area of contact in a semiconductor between P-type material and N-type material

_______m. Component capable of producing an electric current when exposed to light or producing light electronically when power is applied

_______n. Air temperature around a device or circuit

_______o. Sudden increase in current or voltage

_______p. Process of adding impurities to semiconductor material crystals in order to change their electrical properties

_______q. In a semiconductor material, the current carrier that is present in the lesser quantity

_______r. In a semiconductor material, the current carrier that is present in the greater quantity

_______s. Positive electrode of an electrical or electronic device

2. List circuit applications of common discrete semiconductor devices.

- Diodes

    a. ______________________________

    b. ______________________________

- Bipolar transistors

    a. ______________________________

    b. ______________________________

- Field-effect transistors

    a. ______________________________

    b. ______________________________

84

- Unijunction transistors
  a. ______________________________
  b. ______________________________
- Thyristors
  a. ______________________________
  b. ______________________________

3. Distinguish between forward and reverse biasing. Write an "F" beside the description of forward biasing and an "R" beside the description of reverse biasing.

_______a. When the current causes the device to promote electrical flow (be *on*)

_______b. When the current causes the device to oppose electrical flow (be *off*)

4. Complete statements regarding the characteristics of semiconductor materials in constructing electronic devices. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

   a. The ________________ of a semiconductor material can be increased significantly by adding an impurity to the semiconductor through a process called *doping*.

   b. When a semiconductor is doped with an element containing five valence electrons, called a *pentavalent* element, it becomes (N-type, P-type) material.

   c. When a semiconductor is doped with an element containing three valence electrons, called a *trivalent* element, it becomes (N-type, P-type) material.

   d. The majority of current in N-type materials is carried by the ________________.

   e. The majority of current in P-type materials is carried by the ________________.

   f. Impurity atoms in (N-type, P-type) materials are called *donor atoms*.

   g. Impurity atoms in (N-type, P-type) materials are called *acceptor atoms*.

Written Test

5. Distinguish between electrical flow in P- and N-type materials. Write a "P" beside the statement that describes electron flow in P-type material and an "N" beside the statement that describes electron flow in N-type material.

_______a. When voltage is applied, the electrons move from the negative terminal toward the positive terminal of the voltage source

_______b. When voltage is applied, the holes flow from the positive terminal toward the negative terminal of the voltage source

6. Complete statements regarding the characteristics of the P-N junction. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. The structure of semiconductor materials is referred to as _______________.

b. Through various manufacturing methods, semiconductor crystals can be formed so that one portion is P-type material and the other portion is _______________ material.

c. The area between the two types of material is call the *P-N junction* or _______________.

d. The resulting semiconductor device is referred to as a *P-N junction* _______________ or simply *junction* _______________ because it allows current flow in one direction while blocking it in the other direction.

e. Because the junction has no free electrons or holes, it acts as an _______________ or *barrier*.

f. The junction region will continue to act as a barrier until the applied voltage exceeds the *barrier* _______________.

g. In a junction diode, (forward, reverse) biasing results when the negative terminal of the voltage source is attached to the N-type material side of the diode and the positive terminal of the voltage source is attached to the P-type material side of the diode and the voltage is raised beyond the barrier potential.

h. In a junction diode, (forward, reverse) biasing results when the negative terminal of the voltage source is attached to the P-type material side of the diode and the positive terminal of the voltage source is attached to the N-type material side of the diode and the voltage is raised beyond the barrier potential.

i. Some amount of current flow results even with reverse biasing and is referred to as ______________ *current*.

7. Complete statements regarding diode operation. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. The basic diode structure is a two-lead device with (an anode, a cathode) formed by the P-type material section of the diode and (an anode, a cathode) formed by the N-type material section of the diode.

b. Normal current flow through the diode goes from the (cathode to the anode, anode to the cathode).

c. When current is applied to a diode through forward biasing, there is (large, virtually no) flow until the barrier potential is reached.

d. Once past the barrier potential, forward current (increases, decreases) rapidly in a fairly linear fashion.

e. If the forward voltage continues to increase, the diode will be damaged at a characteristic value referred to as ______________ (I_f).

f. When current is applied to a diode through reverse biasing, there is (great, virtually no) flow.

g. At a voltage level referred to as *breakdown* voltage, there is a rapid increase in the reverse current through (majority, minority) carriers.

h. If the reverse voltage continues to increase, the diode will be damaged at a characteristic value referred to as __________________ *(PIV)*.

Written Test

8 Match types of discrete semiconductor diodes to their correct descriptions. Write the corresponding numbers on the blanks provided.

______a. Diode, usually made of gallium semiconductor, that gives off light when forward biased

______b. Diode with a narrow depletion region and a high barrier voltage

______c. Two-terminal device that allows current flow in one direction only

______d. Diode that has a wide depletion region capable of making very fast changes of operating states

______e. Diode with characteristics similar to a conventional diode except that it produces a very low forward voltage drop

______f. Diode that operates like a variable capacitor with its two semiconductor regions serving as the capacitor plates and the depletion region serving as a variable space between them

______g. Device that provides AC flow in either direction while still blocking DC

______h. Diode designed to operate at a specific value of reverse breakover with a very stable voltage drop

______i. Diode that produces current proportional to the power level of light that strikes it

______j. Diode constructed with N-type material and a metal anode deposited on the semiconductor material

______k. Diode that operates in its reverse breakdown region that is capable of generating radio frequency power

______l. Device capable of withstanding heavy currents for short periods of time that behaves like a diode because of the alignment of metal (often zinc) oxide grains within its material

1. Backward diode
2. Diode
3. IMPATT diode
4. Light-emitting diode
5. Photodiode
6. PIN diode
7. Schottky diode
8. Thyrector
9. Tunnel diode
10. Varactor
11. Varistor
12. Zener diode

Written Test

9. List uses of discrete semiconductor diodes. For each diode given below, write a use for that diode on the space provided.

   a. Diode (common diode)— ______________________________

   b. Zener (avalanche) diode— ______________________________

   c. Tunnel diode— ______________________________

   d. Backward diode— ______________________________

   e. Photodiode— ______________________________

   f. PIN diode— ______________________________

   g. Light-emitting diode— ______________________________

   h. Schottky (hot carrier) diode— ______________________________

   i. IMPATT (impact avalanche transit time) diode— ______________________________

   j. Varactor (varicap) diode— ______________________________

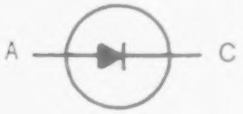
   k. Varistor— ______________________________

   l. Thyrector (bidirectional diode)— ______________________________

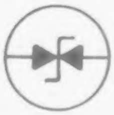
10. Match discrete semiconductor diodes to their correct symbols. Write the corresponding numbers on the blanks provided.

    Note: Some symbols may apply to more than one diode. Answers continue on next page.

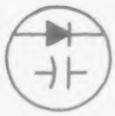
______a.



______b.



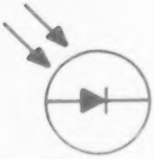
______c.



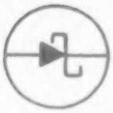
1. Backward diode
2. Diode
3. IMPATT diode
4. Light-emitting diode
5. Photodiode
6. PIN diode
7. Schottky diode
8. Thyrector

Written Test

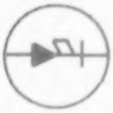
______d.



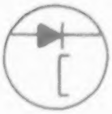
______e.



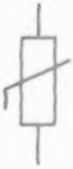
______f.



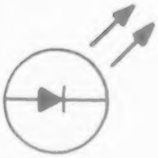
______g.



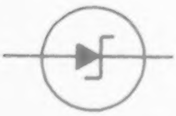
______h.



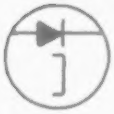
______i.



______j.



______k.



9. Tunnel diode
10. Varactor
11. Varistor
12. Zener diode

Written Test

11. List reasons for diode failure.

a. ____________________________________

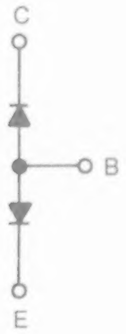
b. ____________________________________

c. ____________________________________

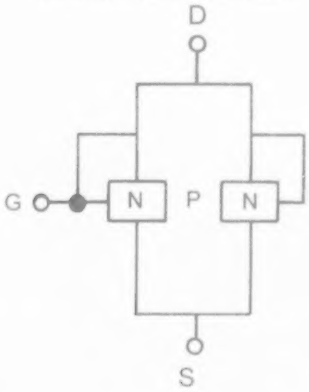
12. Identify transistors by their structures and their electrical equivalents. In the space provided, state whether the structure or electrical equivalent shown is for:

- An NPN bipolar junction transistor
- A PNP bipolar junction transistor
- An N-channel field-effect transistor
- A P-channel field-effect transistor
- A unijunction transistor with an N-type material base
- A unijunction transistor with a P-type material base

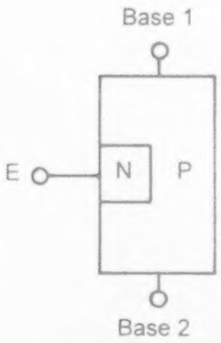
a. ____________________



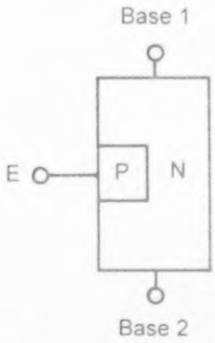
b. ____________________



c. ____________________

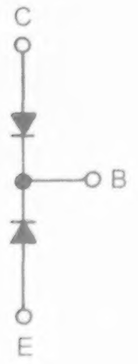


d. ____________________

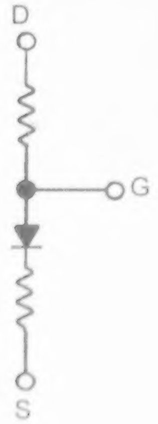


Written Test

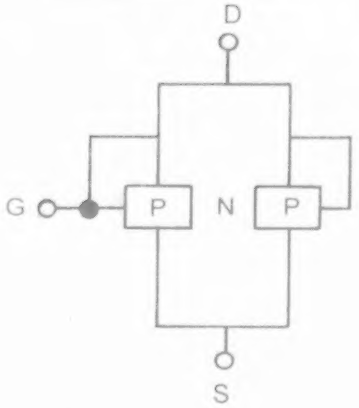
e. ____________________



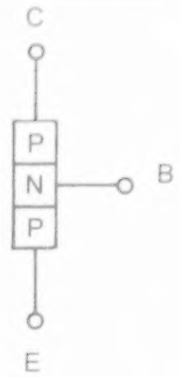
f. ____________________



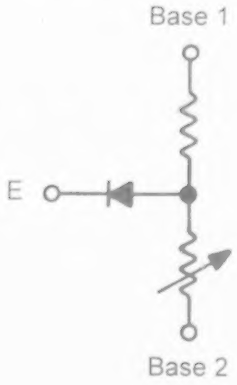
g. ____________________



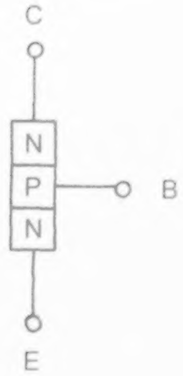
h. ____________________



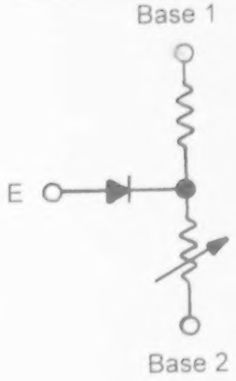
i. ____________________


Base 1
E
Base 2

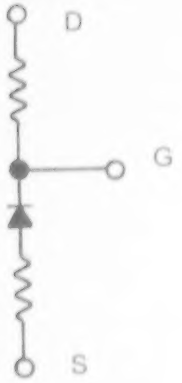
j. ____________________



k. ______________________



l. ______________________



13. Match types of transistors to their correct descriptions. Write the corresponding numbers on the blanks provided.

______ a. N-type material body with small region of P-type material that does not penetrate the N-type material completely, resulting in a device that switches on quickly when its standoff voltage is reached

______ b. Transistor that uses gate voltage to control the resistance of an internal channel and that operates in the depletion mode

______ c. Transistor with an emitter consisting of N-type material, a base of P-type material, and a collector of N-type material

______ d. Transistor with an emitter consisting of P-type material, a base of N-type material, and a collector of P-type material

______ e. Transistor designed to use light as a control source

______ f. FET in which the gate is electrically isolated from the source-drain channel

______ g. Enhanced-mode MOSFET in which the source and drain are located on opposite sides of the substrate layers from each other

1. Complementary metal oxide semiconductor field-effect transistor (C-MOSFET)
2. Complementary unijunction transistor (CUJT)
3. Depletion mode MOSFET
4. Dual-gate JFET
5. Enhancement mode MOSFET
6. Field-effect transistor (FET)
7. Insulated gate bipolar transistor
8. Metal oxide semiconductor field-effect transistor (MOSFET)

Written Test

_____h. MOSFET that is off when the bias voltage is zero

_____i. MOSFET that is on when the bias voltage is zero

_____j. Unijunction transistor that is gated with two internal resistors

_____k. FET that has two external leads for gates

_____l. Circuit configuration using one P-channel MOSFET and one N-channel MOSFET with a shared gate terminal

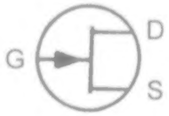
_____m. An enhancement-mode device with vertical structure and a FET-type gate rather than a base lead

_____n. A unijunction transistor with a P-type material body and a small region of N-type material

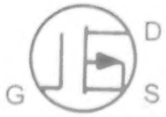
9. NPN transistor
10. Phototransistor
11. PNP transistor
12. Programmable unijunction transistor
13. Unijunction transistor
14. Vertical metal oxide semiconductor field-effect transistor

14. Match types of transistors to their correct symbols. Write the corresponding numbers on the blanks provided.

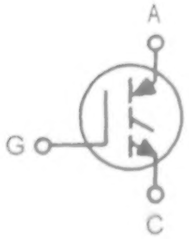
_____a.



_____b.

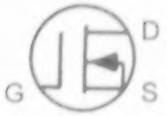


_____c.

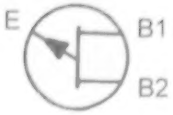


1. Complementary unijunction transistor
2. Dual-gate JFET
3. Field-effect transistor
4. Insulated gate bipolar transistor
5. Insulated gate FET, N-Channel
6. Insulated gate FET, P-Channel
7. NPN transistor

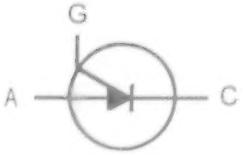
______d.



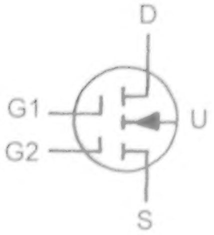
______e.



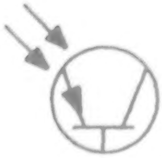
______f.



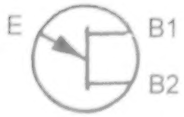
______g.



______h.

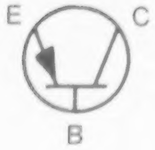


______i.

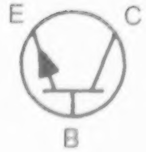


8. Phototransistor
9. PNP transistor
10. Programmable unijunction transistor
11. Unijunction transistor

_____ j.



_____ k.



15. Complete statements regarding the characteristics of bipolar transistors. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

   a. The basic bipolar transistor package has three _______________ referred to as *emitter*, *collector*, and *base*.

   b. The transistor body consists of three sections of _______________ material, put together as NPN or PNP.

   c. The sandwiched material is the (base, collector, emitter).

   d. The emitter section is heavily doped and contains a higher percentage of (majority, minority) carriers, which move through the base and into the collector.

   e. These devices are often called _______________ *junction* transistors because they contain two P-N junctions and both electrons and holes are available as carriers.

   f. The junctions are referred to as the _______________*-base junction* and the _______________*-emitter junction*.

   g. Bipolar transistors are controlled by (current, voltage) and are normally (on, off).

   h. Current through the collector-base junction is (forward, reverse)-biased, while current through the base-emitter junction is (forward, reverse)-biased.

   i. Resistance in the collector-base junction is relatively (high, low), while resistance in the base-emitter junction is relatively (high, low).

Written Test

j. The current through the emitter is equal to ($I_B + I_C$, $I_B - I_C$, $I_B \times I_C$)

k. One of the characteristics of a transistor that may be cited in specifications is the ratio between the collector (current, voltage) and the emitter (current, voltage), which is termed with the Greek letter alpha (α) or α_{DC}.

l. The ratio between the (base, collector) current and (collector, emitter) current is another important characteristic of transistors and is termed with the Greek letter beta (β), β_{DC}, or h_{FE}.

m. Transistor circuits are generally arranged in one of three basic configurations referred to as ________________ (CB), ________________ (CE), and ________________ (CC).

n. Transistors are packaged in several styles of ________________.

16. Describe the operation of an NPN transistor. For each key word or phrase given below, describe how it applies to the operation of an NPN transistor.

a. Free electron flow—____

____

b. Percentage of electrons from emitter and base—____________________________

____

c. Characteristics of base—____

____

17. Describe the operation of a PNP transistor. For each key word or phrase given below, describe how it applies to the operation of a PNP transistor.

a. Free electron flow—____

____

b. Input signal versus current flow—______________________________________

____

c. Characteristics of base—____

____

Written Test

18. Distinguish among characteristics of transistor emitters, bases, and collectors. For each characteristic listed below, write an "E" in the space provided if the characteristic applies to emitters, a "B" if it applies to bases, and a "C" if it applies to collectors.

______a. Are often connected to the metal case of the transistor

______b. Control current flow through the transistor

______c. Are most heavily doped section of a transistor

______d. Provide faster frequency response as they become narrower

______e. Have the most majority current carriers

______f. Carry a large amount of current through the transistor

______g. Are indicated on the transistor symbol by a diagonal line

______h. Are indicated on the transistor symbol by an arrowhead pointing toward the N-type material

______i. Are indicated on the transistor symbol by two perpendicular lines

______j. Divide the N-type and P-type materials

______k. Carry all current that passes into or out of the transistor

______l. Carry only a small portion of the current flowing through the transistor

19. Complete statements regarding the common-base circuit. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. The common-base (CB) circuit uses the base of a ________________ transistor as its common reference point and the emitter and collector leads for the input and output.

b. The CB circuit has a relatively (high, medium, low) voltage gain.

c. The CB circuit has a (high, medium, low) current gain.

d. The CB circuit has a (high, medium, low) power gain.

e. The CB circuit has a (high, medium, low) input impedance.

f. The CB circuit has a (high, medium, low) output impedance.

g. The input signal is (in-phase, out-of-phase) with the output signal.

Written Test

20. Complete statements regarding the common-collector circuit. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

    a. The common-collector (CC) circuit uses the collector of a ______________ transistor as its common reference point and the emitter and base leads for the input and output.

    b. The CC circuit has a (high, medium, low) voltage gain.

    c. The CC circuit has a (high, medium, low) current gain.

    d. The CC circuit has a (high, medium, low) power gain.

    e. The CC circuit has a (high, medium, low) input impedance.

    f. The CC circuit has a (high, medium, low) output impedance.

    g. The input signal is (in-phase, out-of-phase) with the output signal.

21. Complete statements regarding the common-emitter circuit. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

    a. The common-emitter (CE) circuit uses the emitter of a ______________ transistor as its common reference point and the base and collector leads for the input and output.

    b. The CE circuit has a (high, medium, low) voltage gain.

    c. The CE circuit has a (high, medium, low) current gain.

    d. The CE circuit has a (high, medium, low) power gain.

    e. The CE circuit has a (high, medium, low) input impedance.

    f. The CE circuit has a (high, medium, low) output impedance.

    g. The input signal is(in-phase, out-of-phase) with the output signal.

22. State the purpose of biasing in bipolar transistor circuits.

Written Test

23. Match methods for biasing bipolar transistors to their correct descriptions. Write the corresponding numbers on the blanks provided.

______a. Use of a steady DC voltage applied to the transistor base lead to drive the transistor to its operating point

______b. Use of a resistive feedback circuit connected between the collector supply voltage and the load resistor

______c. Use of a four-resistor circuit with resistors across the collector-base junction and the emitter-base junction so that the emitter current remains virtually independent of β

______d. Use of a resistive feedback circuit connected to the collector so that a drop in collector voltage will lead to rise in feedback voltage to the collector

1. Base biasing
2. Collector feedback biasing
3. Emitter feedback biasing
4. Voltage divider biasing

24. Complete statements regarding field effect transistors. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. The basic FET package has three leads referred to as ______________, ______________, and ______________.

b. The transistor body consists of three sections of semiconductor material, put together as two small areas called *regions* and a larger bulk substrate called the ______________.

c. The FET is referred to by the material that composes its channel section as either a ______________ or ______________ FET.

d. FETs are controlled by (current, voltage) and are normally (on, off).

e. The FET functions essentially as a __________________ with two resistances consisting of the drain resistance and the channel resistance.

f. Application of a (positive, negative) voltage relative to the source causes the P-N junction to become reverse-biased, leading to a growth in the depletion region.

g. The larger the depletion regions grow, the (wider, narrower) the channel becomes and the higher the resistance offered by the FET.

h. If the voltage continues to increase, it will eventually reach a point where the reverse bias induced in the depletion regions and the increased resistance in the channel will not allow the current to increase further; this current limiting level is referred to as the FET's *current* _______________ *voltage* (V_p).

i. Because the gate-to-source current is essentially shorted at the ____________ voltage, the current value for the drain-source current is referred to as the *drain-source shorted current* (I_{dss}).

j. FETs operated with drain-source voltages (greater, lower) than the pinch-off value are generally used as amplifiers, while those operated with (greater, lower) drain-source voltages are used as switches.

k. One of the characteristics of a FET that may be cited in specifications is the ratio between the channel current change (ΔI_d) and the gate-to-source voltage change (ΔV_{gs}), which is termed _______________ (g_m) or *forward transfer admittance* (Y_{fs}).

l. The gate-to-source voltage required to reduce the (drain, gate, source) voltage to zero is called the *gate-to-source cutoff voltage.*

m. FET circuits are generally arranged in one of three basic configurations referred to as _______________ (CG), _______________ (CS), and _______________ (CD).

n. FETs are packaged in several styles of _______________.

25. Complete statements regarding the common-gate circuit. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. The common-gate (CG) circuit uses the gate of a _______________ as its common reference point and the source and drain leads for the input and output.

b. The CG circuit has a (high, medium, low) voltage gain.

c. The CG circuit has a (high, medium, low) current gain.

d. The CG circuit has a (high, medium, low) power gain.

e. The CG circuit has a (high, medium, low) input impedance.

f. The CG circuit has a (high, medium, low) output impedance.

g. The input signal is (in-phase, out-of-phase) with the output signal.

26. Complete statements regarding the common-drain circuit. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. The common-drain (CD) circuit uses the drain of a _______________ as its common reference point and the source and gate leads for the input and output.

b. The CD circuit has a (high, medium, low) voltage gain.

c. The CD circuit has a (high, medium, low) current gain.

d. The CD circuit has a (high, medium, low) power gain.

e. The CD circuit has a (high, medium, low) input impedance.

f. The CD circuit has a (high, medium, low) output impedance.

g. The input signal is (in-phase, out-of-phase) with the output signal.

27. Complete statements regarding the common-source circuit. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. The common-source (CS) circuit uses the source of a _______________ as its common reference point and the gate and drain leads for the input and output.

b. The CS circuit has a relatively (high, medium, low) voltage gain.

c. The CS circuit has a (high, medium, low) current gain.

d. The CS circuit has a very (high, medium, low) power gain.

e. The CS circuit has a (high, medium, low) input impedance.

f. The CS circuit has a (high, medium, low) to (high, medium, low) output impedance.

g. The input signal is (in-phase, out-of-phase) with the output signal.

28. State the purpose of biasing in FET circuits.

____

____

____

29. Match methods for biasing FETs to their correct descriptions. Write the corresponding numbers on the blanks provided.

______a. Use of source current flowing through the source resistor to maintain the source terminal positive with respect to ground

______b. Use of a separate bias supply across the gate-source junction to maintain the gate current near zero

______c. Use of a voltage divider to provide a fixed positive voltage to the gate terminal and source bias

1. Combination biasing
2. Fixed biasing
3. Source biasing

30. Complete statements regarding insulated gate field effect transistors. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. The basic IGFET package has three leads referred to as *gate*, *source*, and *drain*, but may have a second external ________________ and an external lead for the substrate.

b. The IGFET body consists of (two, three) sections of semiconductor material, put together as a *channel* that connects to the source and drain terminals and a larger bulk substrate.

c. The IGFET uses a metal gate that is electrically (connected to, isolated from) the semiconductor channel by a thin oxide layer, such as silicon dioxide.

d. IGFETs can be either *enhancement mode* or *depletion mode* devices based on their conducting state when the bias voltage is zero, with (enhancement, depletion) mode IGFETs not conducting with zero bias voltage and (enhancement, depletion) mode devices conducting at zero bias voltage.

e. Enhancement mode IGFETs are normally (on, off) devices and do not normally have a conductive channel, as indicated by the broken line between the source and the drain in the symbol for such a device.

f. Depletion mode IGFETs are normally (on, off) devices that normally have a conductive channel, as indicated by the solid line between the source and the drain in the symbol for such a device.

g. As the voltage (increases, decreases) in an enhancement mode IGFET, the gate becomes more positive, causing the channel conduction to improve and the drain current to increase.

h. A depletion mode IGFET will operate in the depletion mode when a (positive, negative) voltage is applied to the gate and in an enhancement mode when a (positive, negative) voltage is applied to the gate, so that the device is sometimes referred to as a *depletion-enhancement MOSFET*.

31. Select from a list correct handling precautions for IGFETs. Write an "X" beside each item listed below that is a correct handling precaution for IGFETs.

______a. Short device leads together during handling.

______b. IGFETs should only be handled at approved ESD workstations.

______c. Never transport more than one IGFET in the same container.

______d. Soldering equipment used on IGFETs should be grounded.

______e. Use damaged IGFETs as regular FETs if they test good.

______f. IGFETs or circuitry that includes IGFETs should never be installed or removed from equipment under power.

______g. IGFETs should be handled gently and never transported without adequate ESD-qualified packaging.

______h. Solder IGFETs at temperatures less than 300° F to avoid thermal damage.

32. List characteristics of an ideal amplifier.

a. ______________________________

b. ______________________________

c. ______________________________

Written Test

33. Select from a list ways of classifying amplifiers. Write an "X" beside each item listed below that is a way of classifying amplifiers.

______a. Minimum input voltage

______b. Class

______c. Application

______d. Number of diodes

______e. Coupling

______f. Number of amplifiers in circuit

______g. Circuit configuration

______h. Performance characteristics

34. Describe the operation of a single-stage amplifier circuit. For each key word or phrase given below, describe how it applies to the operation of a single-stage amplifier circuit.

a. Purpose of amplifiers—____

____

b. Reduction of electrical characteristics—______________________________

____

c. Gain ratio formulas—____

____

d. If gain is exceeded—____

____

e. Saturation limit—____

____

f. Cutoff limit—____

____

g. Tuning—____

____

h. Maximizing power transfer—______________________________

____

i. Multistage amplifiers—______________________________

____

j. Feedback—______________________________

____

k. Negative feedback—______________________________

____

l. Break frequency—______________________________

____

m. Load lines—______________________________

____

35. Complete statements regarding the characteristics of power amplifiers. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. Amplifiers that have relatively small (saturation, cutoff) levels are referred to as *small-signal amplifiers* or *voltage amplifiers* and their output is normally evaluated in terms of voltage.

b. Amplifiers that work with relatively large (saturation, cutoff) points are referred to as *large-signal amplifiers* or *power amplifiers* and their output is measured in watts.

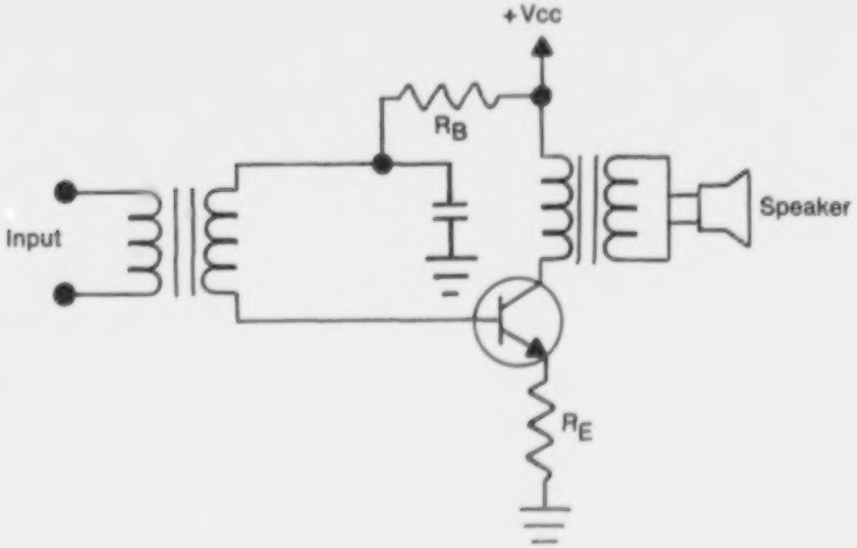
c. A power amplifier is likely to be the (first, last) stage of amplification in a multistage system.

d. Power amplifiers should have very (high, low) output impedance.

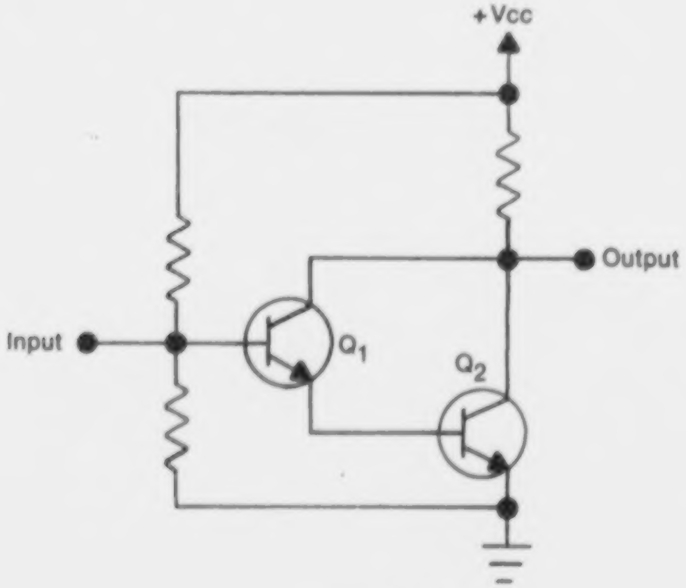
e. One evaluation of a power amplifier is its ______________, which is a comparison of its output power and its DC input power.

36. Identify transistor configurations of power amplifiers.

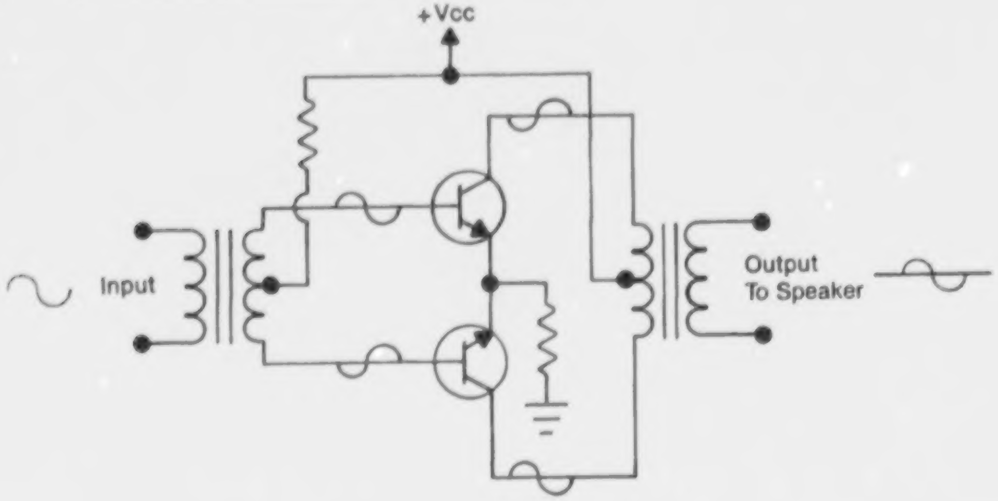
a. ______________________________


+Vcc
R_B
Input
Speaker
R_E

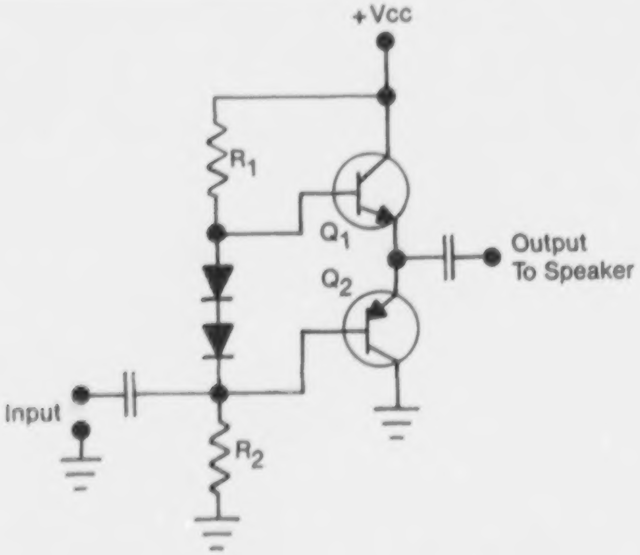
b. ______________________________


+Vcc
Output
Input
Q1
Q2

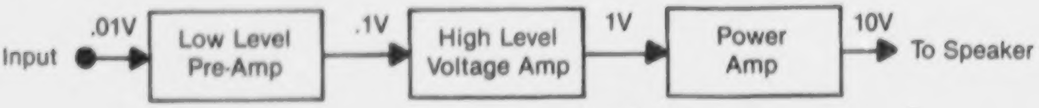
c. ______________________________


+Vcc
Input
Output
To Speaker

d. ______________________________


+Vcc
R1
Q1
Q2
Output
To Speaker
Input
R2

e. ______________________________


Input
.01V
Low Level
Pre-Amp
.1V
High Level
Voltage Amp
1V
Power
Amp
10V
To Speaker

Written Test

37. Describe amplifier operating conditions. For each key word or phrase given below, describe how it applies to amplifier operating conditions.

a. Saturation—____

____

b. Cutoff—____

____

c. Active—____

____

38. Match methods of coupling transistor amplifier circuits to their correct descriptions. Write the corresponding numbers on the blanks provided.

______a. Coupling that employs blocking capacitors and resistors in the supply path

______b. Coupling by use of a semiconductor device that contains an infrared light-emitting diode, an enclosed light path, and a photodetector to allow signal transfer without electrical connection between the two circuits

______c. Coupling through the use of a combination of capacitors and windings

______d. Coupling through inductance produced in transformers

______e. Coupling by actually joining separate circuits with conductors

1. Direct coupling
2. Impedance coupling
3. Optocoupling
4. Resistance-capacitance coupling
5. Transformer coupling

39. Identify classes of transistor amplifier circuits by characteristics of the circuit. In the space provided by each list of characteristics, write the letter or letters of the class of amplifiers (A, B, C, D, or AB) to which the characteristics apply.

______a. AC waveform is converted to variable width pulses, with the width related to the sampled amplitude of the AC waveform

- Bias varies with waveform
- Efficiency is approximately 85-95%
- Distortion is very high
- Used in high-efficiency audio amplifiers

______b. Complete sine wave appears at a single transistor output

- Bias point is approximately halfway between cutoff and saturation
- Efficiency is approximately 25%
- Distortion is low
- Used mostly in small-signal amplifiers

______c. Transistor is tuned for more than half but less than all of the sine wave

- Bias is near but above cutoff
- Efficiency is approximately 60-65%
- Distortion is moderate
- Used in high-power applications for both audio and radio frequency applications

______d. Transistor is on for half of the input sine wave

- Bias point is at cutoff
- Efficiency is approximately 75%
- Distortion is high
- Used mostly in high power applications but not radio frequency operations

______e. Transistor is tuned for less than half of the input sine wave

- Bias point is beyond cutoff
- Efficiency is approximately 90-95%
- Distortion is very high
- Used in radio frequency applications

40. Arrange in order the steps for troubleshooting transistor amplifier circuits. Write a "1" beside the step that should be done first, a "2" beside the step that should be done second, etc.

______a. Make DC voltage checks with a voltmeter to find any biasing problems, checking high-power components first.

______b. Inspect the equipment for obvious symptoms such as burned, overheated, or broken components.

______c. Test individual suspect components.

______d. Check the power supply for normal operation.

______e. Isolate the defective stage by making waveform checks beginning at the output and working back toward the input.

Written Test

41. Complete statements regarding the operation of a unijunction transistor. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. The unijunction transistor package has three leads referred to as ______________, ______________, and ______________.

b. The transistor body consists of (P-type, N-type) material connected to the two base leads.

c. The emitter and a small region of (P-type, N-type) material are embedded in the substrate.

d. UJTs exhibit (positive, negative) resistance—that is, as the voltage in the circuit decreases, current increases.

e. The UJT is forward biased with voltage applied to the emitter, causing electrons to flow from base (1, 2) to the emitter and a decrease in resistance between the emitter and base (1, 2) allowing even more current flow.

f. Voltage continues to build until the UJT reaches its *standoff voltage* or *peak voltage*, which latches the transistor (on, off) and allows the current to continue to increase while the voltage decreases.

g. The transistor will continue to conduct as long as the emitter current remains above a minimum value termed the transistor's ______________ current.

h. Unijunction transistors are controlled by (current, voltage) and are normally (on, off).

i. After the UJT latches on, voltage will continue to drop until the resistance in the base 1 circuit reaches its lowest point, referred to as the ______________ point.

j. If voltage increases from the valley point, there will be a linear (increase, decrease) in current.

k. One of the characteristics of a unijunction transistor that may be cited in specifications is the ratio between the base 1 and base 2 ______________, which is called *intrinsic standoff ratio,* termed with the Greek letter eta (η).

l. The major uses for UJTs are to trigger other devices, like SCRs, and in ______________.

m. UJTs (are, are not) used in amplifiers.

Written Test

42. State the purpose of each section of an oscillator circuit.

a. Frequency determining network—________________________________

____

b. Amplifier stage—____

____

c. Positive feedback circuit—______________________________

____

d. DC power supply—_______________________________________

____

e. Self-starting oscillator device—__________________________

____

43. Match common oscillator configurations to their correct descriptions. Write the corresponding numbers on the blanks provided.

______a. Uses a tapped coil in series with or as a shunt to a bipolar transistor or FET amplifier for in-phase feedback

______b. Uses a small coil referred to as a *tickler coil* wired in series with or as a shunt to a bipolar transistor amplifier to provide regenerative feedback through inductive coupling

______c. Uses a tank circuit that is divided into input and feedback portions by a capacitive voltage divider with either a bipolar or FET amplifier

1. Armstrong oscillator
2. Colpitts oscillator
3. Hartley oscillator

Written Test

44. Match thyristors to their correct descriptions. Write the corresponding numbers on the blanks provided.

______a. A gated diode that does not begin forward conduction until triggered

______b. An SCR that is gated to the anode

______c. An SCR that can be triggered with light

______d. An SCR that is gated to both the anode and cathode

______e. An SCR with an internal zener circuit on the anode gate

______f. An SCR with an internal zener on each gate

______g. A bidirectional device used to gate other devices

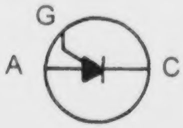
______h. A diac with a gate

1. Complementary silicon-controlled rectifier
2. Diac
3. Light-activated silicon-controlled rectifier
4. Silicon bilateral switch
5. Silicon-controlled rectifier
6. Silicon-controlled switch
7. Silicon unilateral switch
8. Triac

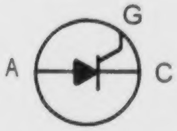
45. Identify thyristors by their symbols and their electrical equivalents. In the space provided, state whether the symbol or electrical equivalent shown is for:

- SCR
- CSCR
- LASCR
- SCS
- Bilateral switch
- Unilateral switch
- Diac
- Triac

a. ____________________

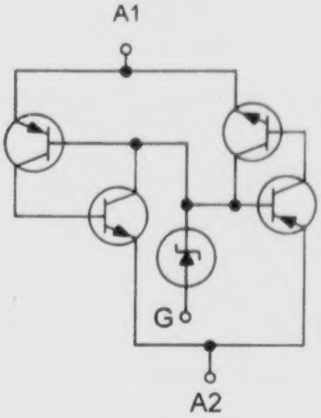


b. ____________________

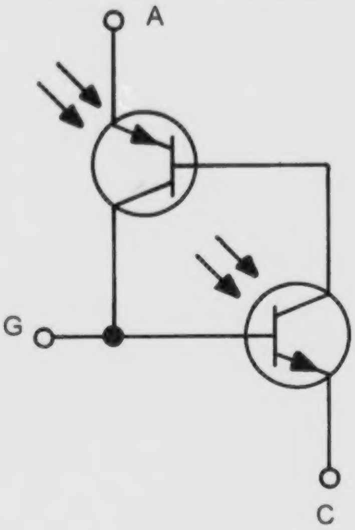


Written Test

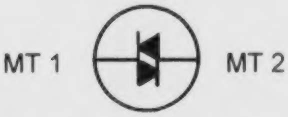
c. ______________________



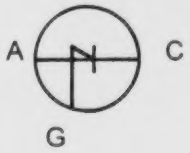
d. ______________________



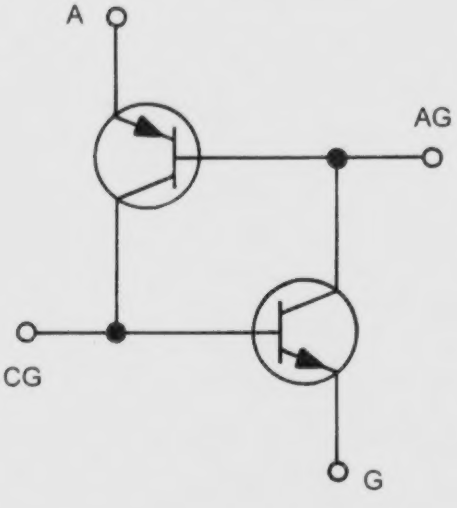
e. ______________________



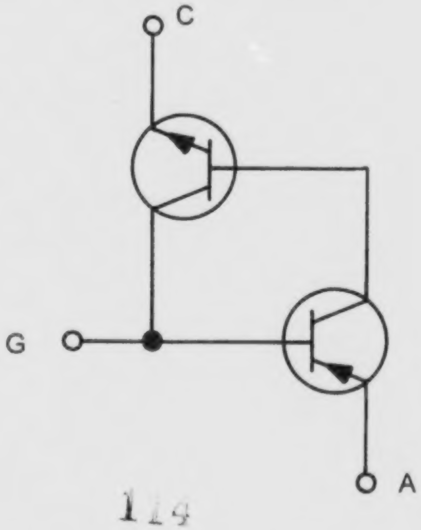
f. ______________________



g. ______________________

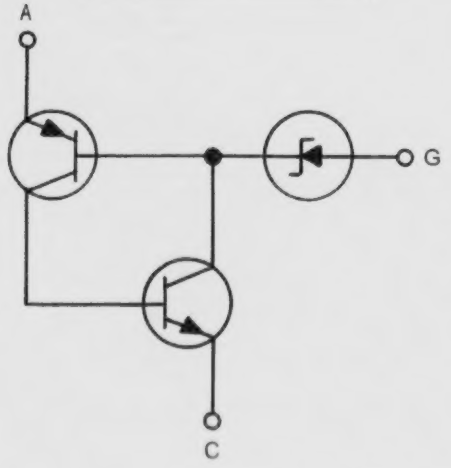


h. ______________________

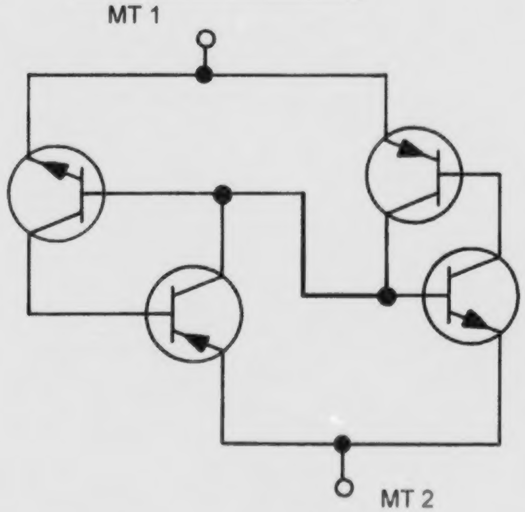


Written Test

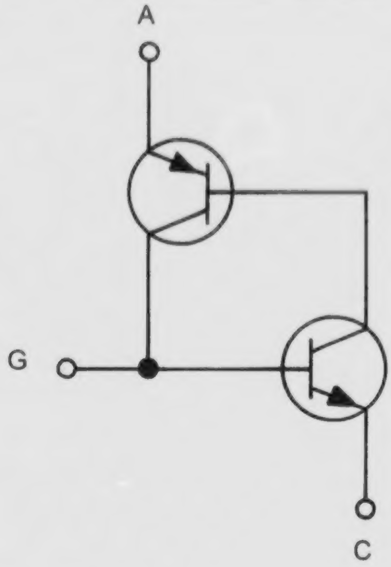
i. ______________________



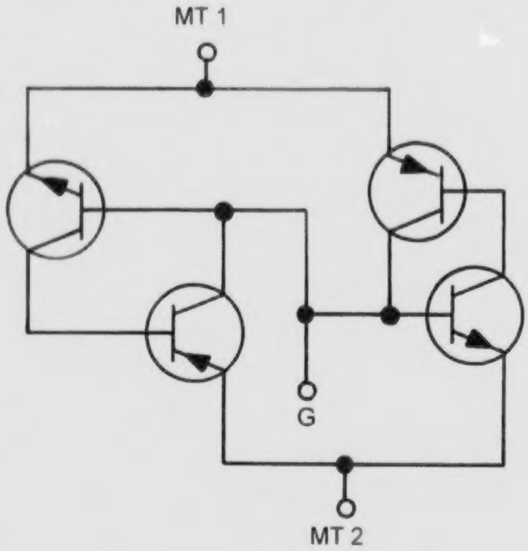
j. ______________________



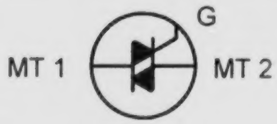
k. ______________________



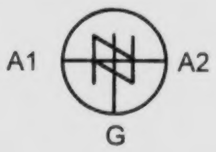
l. ______________________



m. ______________________

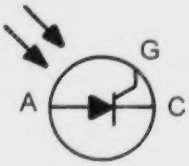


n. ______________________

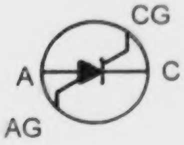


Written Test

o. ____________________

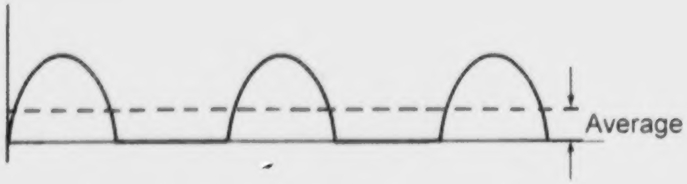


p. ____________________

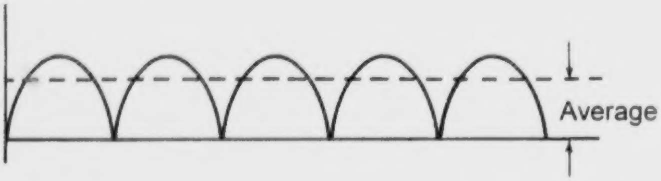


46. Identify rectified waveforms.

a. ______________________________

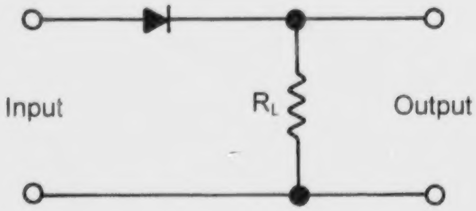


b. ______________________________



47. Match rectifier circuits to their correct schematics. Write the corresponding numbers on the blanks provided.

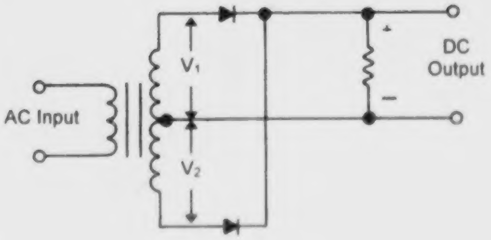
______a.



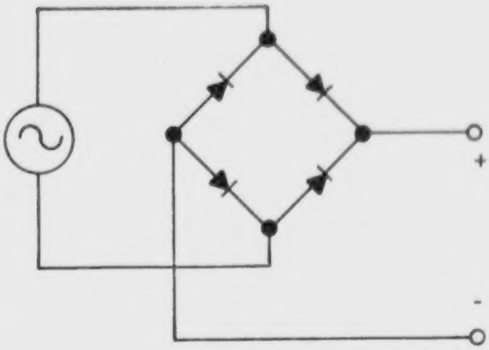
1. Bridge rectifier
2. Full-wave rectifier
3. Half-wave rectifier
4. SCR
5. Triac

Written Test

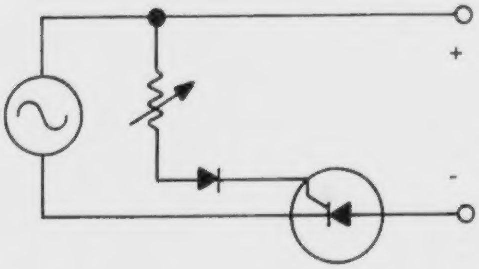
_______b.


V₁
AC Input
V₂
+
DC Output
−

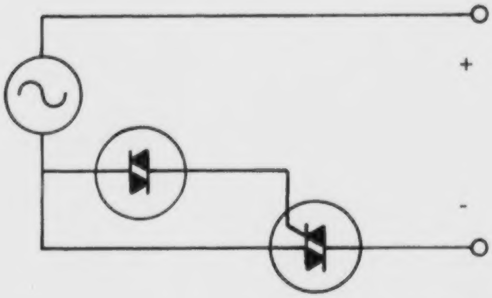
_______c.



_______d.

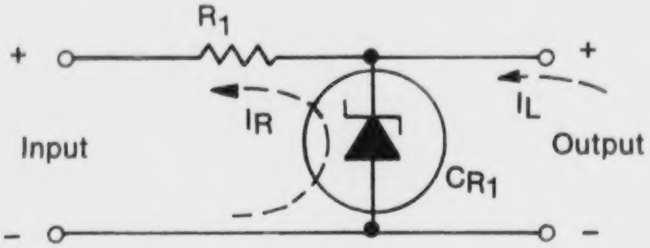


_______e.

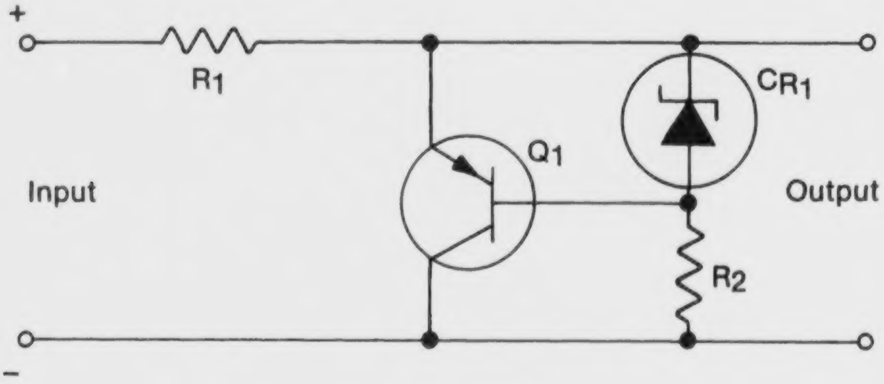


48. Identify types of voltage regulators by their schematics.

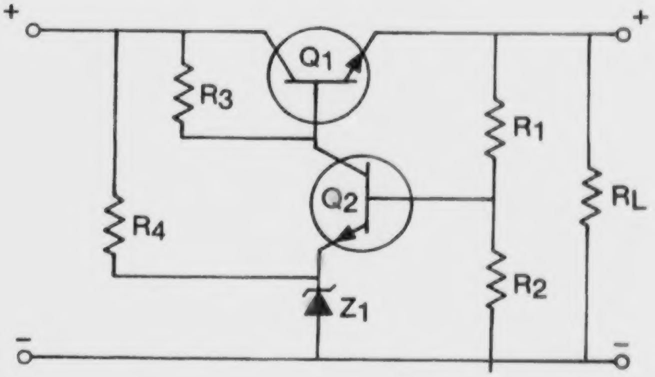
a. ______________________________


R1
+
+
IR
IL
Input
Output
CR1
–
–

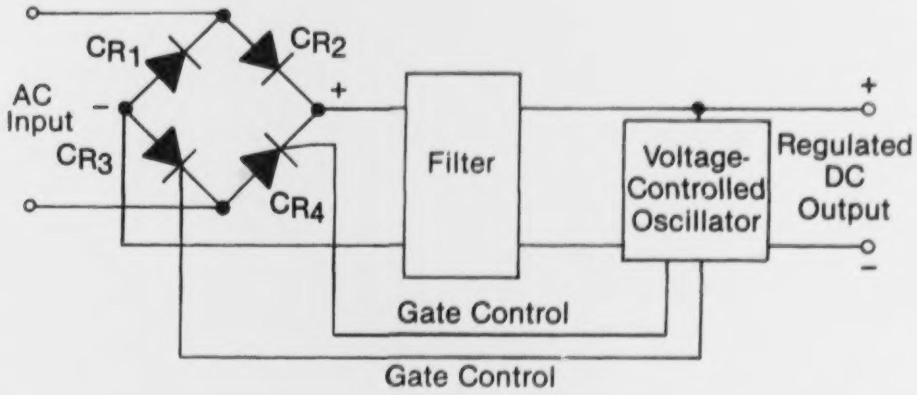
b. ______________________________


+
R1
CR1
Q1
Input
Output
R2
–

c. ______________________________


+
+
Q1
R3
R1
Q2
RL
R4
R2
Z1
–
–

d. ______________________________


CR1
CR2
CR3
CR4
AC Input
–
+
Filter
Voltage-Controlled Oscillator
+
Regulated DC Output
–
Gate Control
Gate Control

*Permission to duplicate this test is granted.

Discrete Semiconductor Devices and Circuits
Unit 1

Unit Evaluation Form

Student Name ______________________________ Unit Rating ______________

Assignment Sheet Ratings

Assignment Sheet 1—Use Resource Materials to Determine Pin Configurations for Common Types of Semiconductor Devices Rating _____

Comments: ____

____

Assignment Sheet 2—Interpret Functions of Electronic Circuits Constructed from Discrete Semiconductor Components Rating _____

Comments: ____

____

Assignment Sheet 3—Label the Parts of a Transistor Circuit Rating _____

Comments: ____

____

Assignment Sheet 4—Construct a Load Line for a Common-Emitter Amplifier Circuit Rating _____

Comments: ____

____

Assignment Sheet 5—Calculate the Gain of Amplifier Circuits Rating _____

Comments: ____

____

Assignment Sheet 6—Compute Voltage, Current, and Power Stage Gain in Decibels Rating _____

Comments: ____

____

Unit Evaluation Form

Assignment Sheet 7—Calculate the Overall Gain of Multistage Amplifiers Rating _____

Comments ______________________________

Assignment Sheet 8—Identify Types of Transistors Used in Oscillators Rating _____

Comments: ______________________________

Job Sheet Ratings

Job Sheet 1—Perform a Static Test of Semiconductor Diodes Rating _____

Comments: ______________________________

Job Sheet 2—Test a Semiconductor Diode and Plot Characteristic Curves Rating _____

Comments: ______________________________

Job Sheet 3—Construct and Test a Half-Wave Rectifier Circuit Rating _____

Comments: ______________________________

Job Sheet 4—Construct and Test a Full-Wave Rectifier Circuit Rating _____

Comments: ______________________________

Job Sheet 5—Test and Replace Light-Sensitive Devices Rating _____

Comments: ______________________________

Unit Evaluation Form

Job Sheet 6—Test Transistors Rating _____

Comments: ____

____

Job Sheet 7—Construct and Test a Common-Emitter Circuit Rating _____

Comments: ____

____

Job Sheet 8—Construct and Test a Common-Base Circuit Rating _____

Comments: ____

____

Job Sheet 9— Construct and Test a Common-Collector Circuit Rating _____

Comments: ____

____

Job Sheet 10—Plot a Transistor Output Characteristic Curve Rating _____

Comments: ____

____

Job Sheet 11—Construct and Test a Single-Ended Amplifier Rating _____

Comments: ____

____

Job Sheet 12—Construct and Test a Push-Pull Amplifier Rating _____

Comments: ____

____

Job Sheet 13—Construct and Test a Two-Stage, Direct-Coupled Amplifier Rating _____

Comments: ____

____

Unit Evaluation Form

Job Sheet 14—Construct and Test a Darlington Pair Amplifier Rating _____

Comments: ______________________________

____

Job Sheet 15—Construct and Test a Hartley Oscillator Rating _____

Comments: ______________________________

____

Job Sheet 16—Test and Replace Silicon-Controlled Rectifier Rating _____

Comments: ______________________________

____

Job Sheet 17—Troubleshoot Discrete Solid-State Device Circuits Rating _____

Comments: ______________________________

____

Written-Test Scores

Pretest _______ Posttest _______ Other _______

Other ______________________________

____

Teacher Signature ______________________ Date ____________

Student Signature ______________________ Date ____________

***Permission to duplicate this form is granted.**

Discrete Semiconductor Devices and Circuits
Unit 1

Supplement 1—Report on a Diode

Introduction The progress that is being made in the development and manufacture of semiconductor devices has been incredible over the past few years, and indications are that this will continue for many years to come. Along with these advances come changes in operation, performance capabilities, handling requirements, fabrication and test procedures, and other characteristics that affect how an electronics technician works with such devices. Therefore, technicians must remain current on developments in the component industry and be able to obtain technical data on new components that they encounter, including devices that may be new to them as they start their careers. This supplement will provide students an opportunity to research information on a semiconductor diode.

Directions Copy the form on the second page following for distribution to the students. Use the information in the introduction to this supplement or similar thoughts to motivate the class on the need to stay current on developments in component technology. Assign each student an appropriate component or allow the students to choose components. Provide the necessary data resources for the students to use in doing their research. Have the students turn in written reports—either the completed forms or more formal reports to your format—or give oral reports to the class so that all students get exposed to the research done by others.

Note: This supplement lends itself for flexible use in the classroom. Consider the following applications and alternatives:

- Use the supplement only for students who are ahead of the rest of the class to expand their studies.
- This supplement is one in a series dealing with the components covered in this unit. Have only portions of the class do each supplement so that the total series is completed by the entire class rather than having each student do each supplement.
- Tailor the complexity of the component to the student's abilities. Have advanced students report on more complex or specialized components, while other students report on the more common applications. For example, one student may report on a conventional diode, while another may report on an infrared LED.
- Use variations in the report format, allowing the students some opportunities for creativity. These variations should be appropriate for the abilities and interests of your students. For example, you may have the students create posters about their assigned components. If you have a computer network available, you can create an "internet" with the

students creating "home pages" that other students can access. You can compile a component catalog using the reports. The catalog may be a book, a computer file, or a videotape of oral reports or posters.

- Have students use the assigned component in a circuit application. For example, assign components that are used in the job sheets and have the students complete their reports before doing the job sheet. Develop additional projects using the assigned components.
- Customize the report form by adding questions that apply specifically to the assigned component, similar to the types of questions that accompany the discussion step of many job sheets.

Supplement 1

Report on a Semiconductor Diode

Student Name ______________________________ Date ______________

Name/Number of Component ____

Manufacturer ____

General uses of component ____________________________________

____

Available packages (materials and types) ______________________

____

Key Characteristics

Note: Characteristics presented in data sheets will vary greatly among components and manufacturers. List the key characteristics provided for each category given below and state what the characteristic is. For example, for voltage, if the data sheet lists nominal operating voltage, maximum forward voltage, and maximum reverse voltage, list those characteristics and state the values given.

Voltage (such as repetitive reverse voltage, zener voltage, forward voltage, breakdown voltage, etc.)

Current (such as average rectified forward current, peak surge current, maximum forward current, etc.)

Power dissipation

Operating and Storage Temperatures

Soldering Temperature, Time, and Solder Flux Specifications

On the back of this sheet, list other characteristics (impedances, capacitances, etc.) or provide sketches of leads, characteristic curves, electrical equivalents, or other data that may be useful.

***Permission to duplicate this form is granted.**

Discrete Semiconductor Devices and Circuits
Unit 1

Supplement 2—Report on a Bipolar Junction Transistor

Introduction The progress that is being made in the development and manufacture of semiconductor devices has been incredible over the past few years, and indications are that this will continue for many years to come. Along with these advances come changes in operation, performance capabilities, handling requirements, fabrication and test procedures, and other characteristics that affect how an electronics technician works with such devices. Therefore, technicians must remain current on developments in the component industry and be able to obtain technical data on new components that they encounter, including devices that may be new to them as they start their careers. This supplement will provide students an opportunity to research information on a bipolar junction transistor.

Directions Copy the form on the next page for distribution to the students. Use the information in the introduction to this supplement or similar thoughts to motivate the class on the need to stay current on developments in component technology. Assign each student an appropriate component or allow the students to choose components. Provide the necessary data resources for the students to use in doing their research. Have the students turn in written reports—either the completed forms or more formal reports to your format—or give oral reports to the class so that all students get exposed to the research done by others.

Note: Supplement 1 contains a number of suggestions on how to present this supplement and customize it for use in your classroom.

Supplement 2

Report on a Bipolar Junction Transistor

Student Name ______________________________ Date ________________

Name/Number of Component ____

Manufacturer ____

General uses of component ____

____

Available packages (materials and types) ____

____

Key Characteristics

Note: Characteristics presented in data sheets will vary greatly among components and manufacturers. List the key characteristics provided for each category given below and state what the characteristic is. For example, for voltage, if the data sheet lists nominal operating voltage, maximum forward voltage, and maximum reverse voltage, list those characteristics and state the values given.

Voltage (such as C-E/C-B voltages, saturation voltage, C-E/E-B breakdown voltages, etc.)

Current (such as collector current, collector cutoff current, etc.)

Gain (DC current gain, bandwidth gain, etc.)

Power dissipation

Operating and Storage Temperatures

Soldering Temperature, Time, and Solder Flux Specifications

On the back of this sheet, list other characteristics (impedances, capacitances, etc.) or provide sketches of leads, characteristic curves, electrical equivalents, or other data that may be useful.

***Permission to duplicate this form is granted.**

Discrete Semiconductor Devices and Circuits
Unit 1

Supplement 3—Report on a Field-Effect Transistor

Introduction The progress that is being made in the development and manufacture of semiconductor devices has been incredible over the past few years, and indications are that this will continue for many years to come. Along with these advances come changes in operation, performance capabilities, handling requirements, fabrication and test procedures, and other characteristics that affect how an electronics technician works with such devices. Therefore, technicians must remain current on developments in the component industry and be able to obtain technical data on new components that they encounter, including devices that may be new to them as they start their careers. This supplement will provide students an opportunity to research information on a field-effect transistor.

Directions Copy the form on the next page for distribution to the students. Use the information in the introduction to this supplement or similar thoughts to motivate the class on the need to stay current on developments in component technology. Assign each student an appropriate component or allow the students to choose components. Provide the necessary data resources for the students to use in doing their research. Have the students turn in written reports—either the completed forms or more formal reports to your format—or give oral reports to the class so that all students get exposed to the research done by others.

Note: Supplement 1 contains a number of suggestions on how to present this supplement and customize it for use in your classroom.

Supplement 3

Report on a Field-Effect Transistor

Student Name ______________________________ Date ______________

Name/Number of Component ______________________________________

Manufacturer ____

General uses of component ______________________________________

____

Available packages (materials and types) ____________________________

____

Key Characteristics

Note: Characteristics presented in data sheets will vary greatly among components and manufacturers. List the key characteristics provided for each category given below and state what the characteristic is. For example, for voltage, if the data sheet lists nominal operating voltage, maximum forward voltage, and maximum reverse voltage, list those characteristics and state the values given.

Voltage (such as D-S/D-G voltages, reverse G-S voltage, G-S/E-B breakdown voltages, etc.)

Current (such as gate current, gate reverse current, zero-gate-voltage drain current, etc.)

Gain (DC current gain, bandwidth gain, etc.)

Power dissipation

Operating and Storage Temperatures

Soldering Temperature, Time, and Solder Flux Specifications

On the back of this sheet, list other characteristics (admittances, capacitances, etc.) or provide sketches of leads, characteristic curves, electrical equivalents, or other data that may be useful.

***Permission to duplicate this form is granted.**

Discrete Semiconductor Devices and Circuits
Unit 1

Supplement 4—Report on an Insulated-Gate FET

Introduction The progress that is being made in the development and manufacture of semiconductor devices has been incredible over the past few years, and indications are that this will continue for many years to come. Along with these advances come changes in operation, performance capabilities, handling requirements, fabrication and test procedures, and other characteristics that affect how an electronics technician works with such devices. Therefore, technicians must remain current on developments in the component industry and be able to obtain technical data on new components that they encounter, including devices that may be new to them as they start their careers. This supplement will provide students an opportunity to research information on an insulated-gate transistor.

Directions Copy the form on the next page for distribution to the students. Use the information in the introduction to this supplement or similar thoughts to motivate the class on the need to stay current on developments in component technology. Assign each student an appropriate component or allow the students to choose components. Provide the necessary data resources for the students to use in doing their research. Have the students turn in written reports—either the completed forms or more formal reports to your format—or give oral reports to the class so that all students get exposed to the research done by others.

Note: Supplement 1 contains a number of suggestions on how to present this supplement and customize it for use in your classroom.

Report on an Insulated Gate Transistor

Student Name ______________________________ Date ______________

Name/Number of Component ____

Manufacturer ____

General uses of component _______________________________________

____

Available packages (materials and types) _________________________

____

Key Characteristics

Note: Characteristics presented in data sheets will vary greatly among components and manufacturers. List the key characteristics provided for each category given below and state what the characteristic is. For example, for voltage, if the data sheet lists nominal operating voltage, maximum forward voltage, and maximum reverse voltage, list those characteristics and state the values given.

Voltage (such as D-S/D-G voltages, reverse G-S voltage, G-S/E-B breakdown voltages, etc.)

Current (such as gate current, gate reverse current, zero-gate-voltage drain current, etc.)

Gain (small or large signal characteristics as presented)

Power dissipation

Operating and Storage Temperatures

Soldering Temperature, Time, and Solder Flux Specifications

On the back of this sheet, list other characteristics (admittances, capacitances, etc.) or provide sketches of leads, characteristic curves, electrical equivalents, or other data that may be useful.

***Permission to duplicate this form is granted.**

Discrete Semiconductor Devices and Circuits
Unit 1

Supplement 5—Report on a Unijunction Transistor

Introduction The progress that is being made in the development and manufacture of semiconductor devices has been incredible over the past few years, and indications are that this will continue for many years to come. Along with these advances come changes in operation, performance capabilities, handling requirements, fabrication and test procedures, and other characteristics that affect how an electronics technician works with such devices. Therefore, technicians must remain current on developments in the component industry and be able to obtain technical data on new components that they encounter, including devices that may be new to them as they start their careers. This supplement will provide students an opportunity to research information on a unijunction transistor.

Directions Copy the form on the next page for distribution to the students. Use the information in the introduction to this supplement or similar thoughts to motivate the class on the need to stay current on developments in component technology. Assign each student an appropriate component or allow the students to choose components. Provide the necessary data resources for the students to use in doing their research. Have the students turn in written reports—either the completed forms or more formal reports to your format—or give oral reports to the class so that all students get exposed to the research done by others.

Note: Supplement 1 contains a number of suggestions on how to present this supplement and customize it for use in your classroom.

Supplement 5

Report on a Unijunction Transistor

Student Name ______________________________ Date ______________

Name/Number of Component ____

Manufacturer ____

General uses of component ______________________________________

____

Available packages (materials and types) _________________________

____

Key Characteristics

Note: Characteristics presented in data sheets will vary greatly among components and manufacturers. List the key characteristics provided for each category given below and state what the characteristic is. For example, for voltage, if the data sheet lists nominal operating voltage, maximum forward voltage, and maximum reverse voltage, list those characteristics and state the values given.

Voltage (such as interbase voltages, emitter reverse voltage, peak and valley voltages, etc.)

Current (such as holding current, rms emitter current, peak pulse emitter current, peak and valley currents, etc.)

Intrinsic standoff ratio

Power dissipation

Operating and Storage Temperatures

Soldering Temperature, Time, and Solder Flux Specifications

On the back of this sheet, list other characteristics or provide sketches of leads, characteristic curves, electrical equivalents, or other data that may be useful.

*Permission to duplicate this form is granted.

Discrete Semiconductor Devices and Circuits
Unit 1

Supplement 6—Report on a Thyristor

Introduction The progress that is being made in the development and manufacture of semiconductor devices has been incredible over the past few years, and indications are that this will continue for many years to come. Along with these advances come changes in operation, performance capabilities, handling requirements, fabrication and test procedures, and other characteristics that affect how an electronics technician works with such devices. Therefore, technicians must remain current on developments in the component industry and be able to obtain technical data on new components that they encounter, including devices that may be new to them as they start their careers. This supplement will provide students an opportunity to research information on a thyristor.

Directions Copy the form on the next page for distribution to the students. Use the information in the introduction to this supplement or similar thoughts to motivate the class on the need to stay current on developments in component technology. Assign each student an appropriate component or allow the students to choose components. Provide the necessary data resources for the students to use in doing their research. Have the students turn in written reports—either the completed forms or more formal reports to your format—or give oral reports to the class so that all students get exposed to the research done by others.

Note: Supplement 1 contains a number of suggestions on how to present this supplement and customize it for use in your classroom.

Supplement 6

Report on a Thyristor

Student Name ______________________________ Date ______________

Name/Number of Component ____

Manufacturer ____

General uses of component ____

____

Available packages (materials and types) ____________________________

____

Key Characteristics

Note: Characteristics presented in data sheets will vary greatly among components and manufacturers. List the key characteristics provided for each category given below and state what the characteristic is. For example, for voltage, if the data sheet lists nominal operating voltage, maximum forward voltage, and maximum reverse voltage, list those characteristics and state the values given.

Voltage (such as blocking voltages, peak reverse gate voltage, trigger voltage, etc.)

Current (such as average-on current, peak forward gate current, trigger and holding currents, etc.)

Power ratings (peak gate power, average gate power, etc.)

Power dissipation

Operating and Storage Temperatures

Soldering Temperature, Time, and Solder Flux Specifications

On the back of this sheet, list other characteristics (on-off times, rate of rise, etc.) or provide sketches of leads, characteristic curves, electrical equivalents, or other data that may be useful.

*Permission to duplicate this form is granted.

Discrete Semiconductor Devices and Circuits
Unit 1

Supplement 7—Report on an Amplifier Application

Introduction As electronics technicians, your students will be called upon to work with amplifier circuits frequently and in a variety of applications. This unit provides a good opportunity to help students understand the nature and operation of amplifiers before expanding into op-amps in the next unit. Students need to be exposed to a variety of amplifier applications, both single- and multistage configurations. They need to see amplifiers in use with a variety of signal types and in a variety of equipment. This supplement will help increase their knowledge of and experience with amplifiers.

Directions Copy the form on the next page for distribution to the students. Use the information in the introduction to this supplement or similar thoughts to motivate the class on the need to learn about amplifiers. Assign each student an appropriate circuit or allow the students to choose circuits. Provide the necessary data resources for the students to use in doing their research. Have the students turn in written reports—either the completed forms or more formal reports to your format—or give oral reports to the class so that all students get exposed to the research done by others.

Note: Supplement 1 contains a number of suggestions on how to present this supplement and customize it for use in your classroom.

Supplement 7

Report on an Amplifier Application

Student Name ______________________________ Date ______________

Type of Equipment Containing Circuit ______________________________

Manufacturer ______________________________

General Description of Amplifier ______________________________

____

Description of Amplifier Circuit Components ______________________________

____

Note: On the other side of this sheet, sketch the circuit schematic, load lines, frequency response curves, or other data that may be useful.

Gain	Ratio	Decibels
Power	________	________
Voltage	________	________
Current	________	________

Is the signal inverted? Yes ______ No ________

Configuration (C-E, C-D, C-B, etc.) ______________________________

Class (A, B, C, AB, D) ______________________________

Input impedance ______________________________

Output impedance ______________________________

Bandwidth ______________________________

Coupling method, if used ______________________________

Explain why you think this is a good or poor application design: ______________________________

____

***Permission to duplicate this form is granted.**

Supplement 8—Report on an Oscillator Application

Introduction Just as amplifiers are frequently found in electronic equipment, amplifiers with feedback used as oscillators are also common. While many electronic oscillators use op-amps, discrete component oscillators are still in use. Allowing the students to work with discrete component oscillators will allow them to gain a better understanding of oscillators before the next unit, where they will work with op-amp oscillators and ICs with integrated oscillators. This supplement will help increase their knowledge of and experience with oscillators.

Directions Copy the form on the next page and the second page following for distribution to the students. Two forms have been provided to give you an option of using one form with this unit and one with the next unit. The first form is tailored for oscillators that use discrete components, while the second form may be used with integrated oscillators or op-amp based oscillators as presented in the next unit. However, due to the common use of integrated parts in oscillators, both forms are presented here to give you the option of covering integrated circuit oscillators now or with the next unit.

Use the information in the introduction to this supplement or similar thoughts to motivate the class on the need to learn about amplifiers. Assign each student an appropriate circuit or allow the students to choose circuits. Provide the necessary data resources for the students to use in doing their research. Have the students turn in written reports—either the completed forms or more formal reports to your format—or give oral reports to the class so that all students get exposed to the research done by others.

Note: Supplement 1 contains a number of suggestions on how to present this supplement and customize it for use in your classroom.

Supplement 8

Report on an Oscillator Application

Student Name ______________________________ Date ______________

Type of Equipment Containing Circuit ______________________________

Manufacturer ______________________________

General Description of Oscillator ______________________________

____

Description of Oscillator Circuit Components ______________________________

____

Note: On the other side of this sheet, sketch the circuit schematic, its output waveform, and other data that may be useful.

Configuration of Oscillator (if known)

Armstrong ________ Colpitts ________

Hartley ________ Pierce ________

Other ______________________________

Control

Crystal ________ Frequency ________

Other ______________________________

Is the signal inverted? Yes _____ No ______

Frequency range ______________________________

Other key characteristics ______________________________

Explain why you think this is a good or poor application design: ______________

____

____

*Permission to duplicate this form is granted.

140

Supplement 8

Report on an Integrated Circuit Oscillator Application

Student Name ______________________________ Date ______________

Type of Equipment Containing Circuit ______________________________

Manufacturer ______________________________

General Description of Oscillator ______________________________

____

Description of Oscillator Circuit Components ______________________________

____

Note: On the other side of this sheet, sketch the circuit schematic, its output waveform, and other data that may be useful. Show the pin designations of the IC or op-amp.

Configuration of Oscillator (if known)

Armstrong ________ Colpitts ________

Hartley ________ Pierce ________

Other ______________________________

Control

Internal ________ Op-amp ________

Other ______________________________

Is the signal inverted? Yes ______ No ______

Frequency range ______________________________

Other key characteristics ______________________________

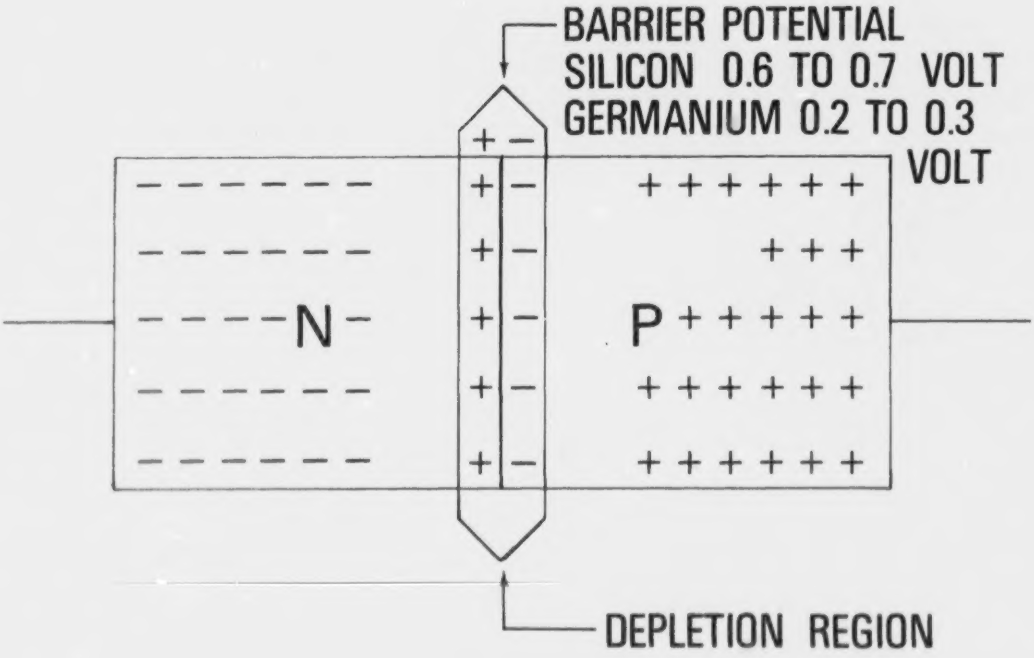
Explain why you think this is a good or poor application design: ______________

____

____

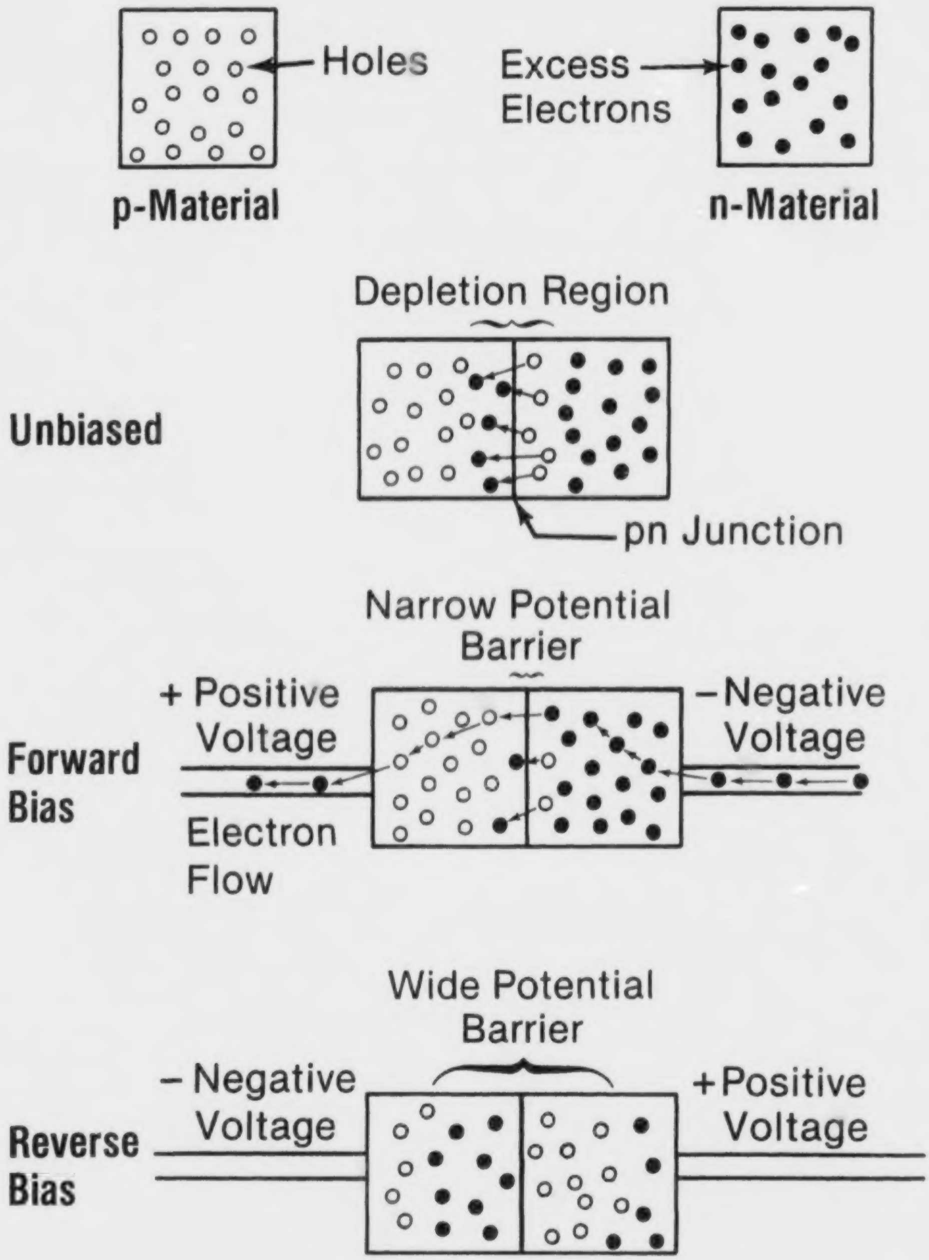
*Permission to duplicate this form is granted.

P-N Junction

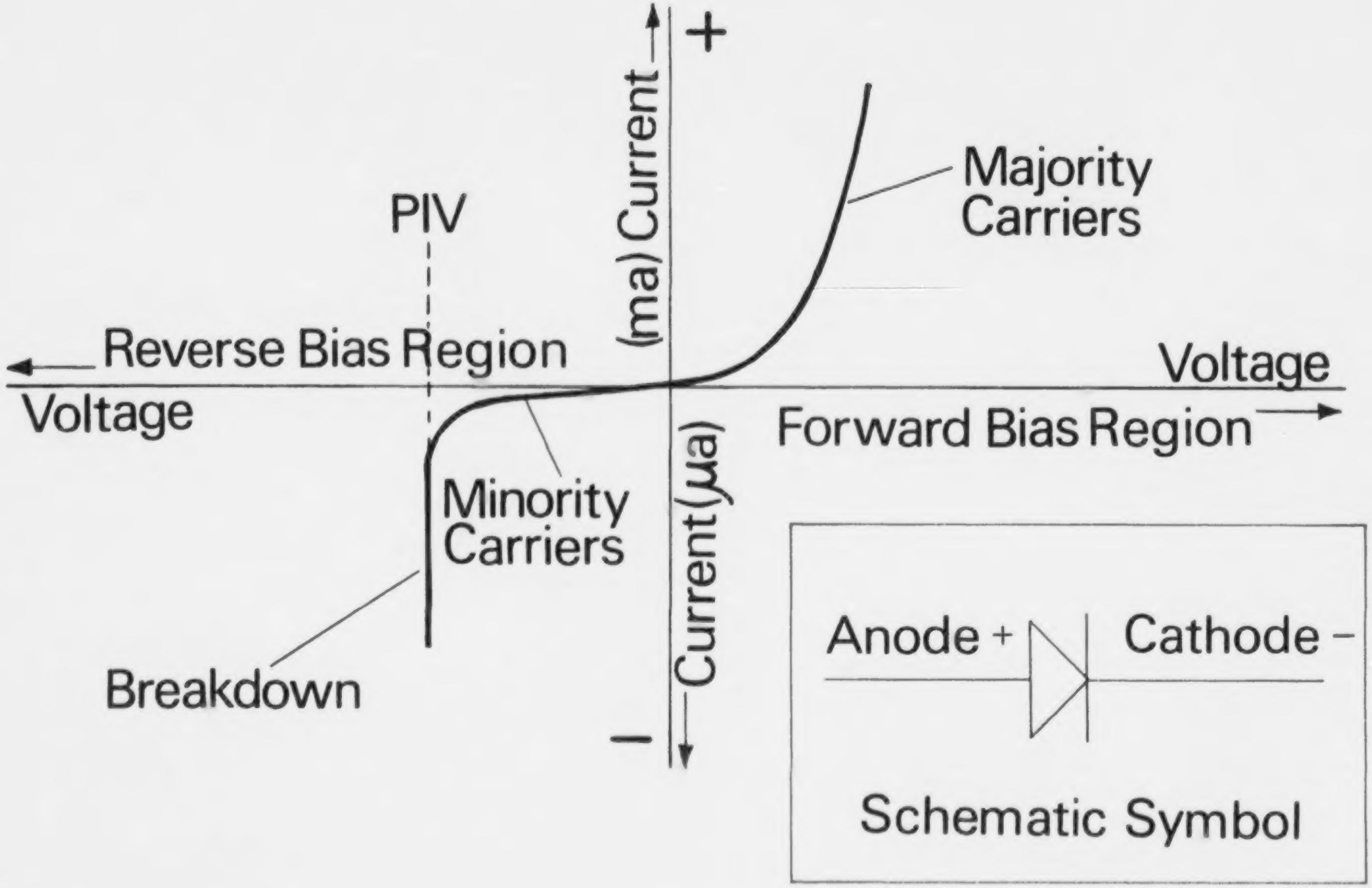

BARRIER POTENTIAL
SILICON 0.6 TO 0.7 VOLT
GERMANIUM 0.2 TO 0.3 VOLT
N
P
DEPLETION REGION

P-N JUNCTION
Showing Barrier Potential
And
Depletion Region

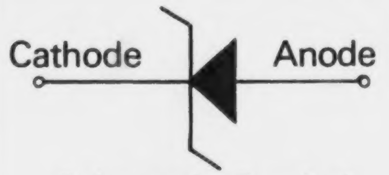
Biasing Effects on the P-N Junction


Holes
p-Material
Excess Electrons
n-Material
Depletion Region
Unbiased
pn Junction
Narrow Potential Barrier
+ Positive Voltage
Forward Bias
Electron Flow
– Negative Voltage
Wide Potential Barrier
– Negative Voltage
Reverse Bias
+ Positive Voltage

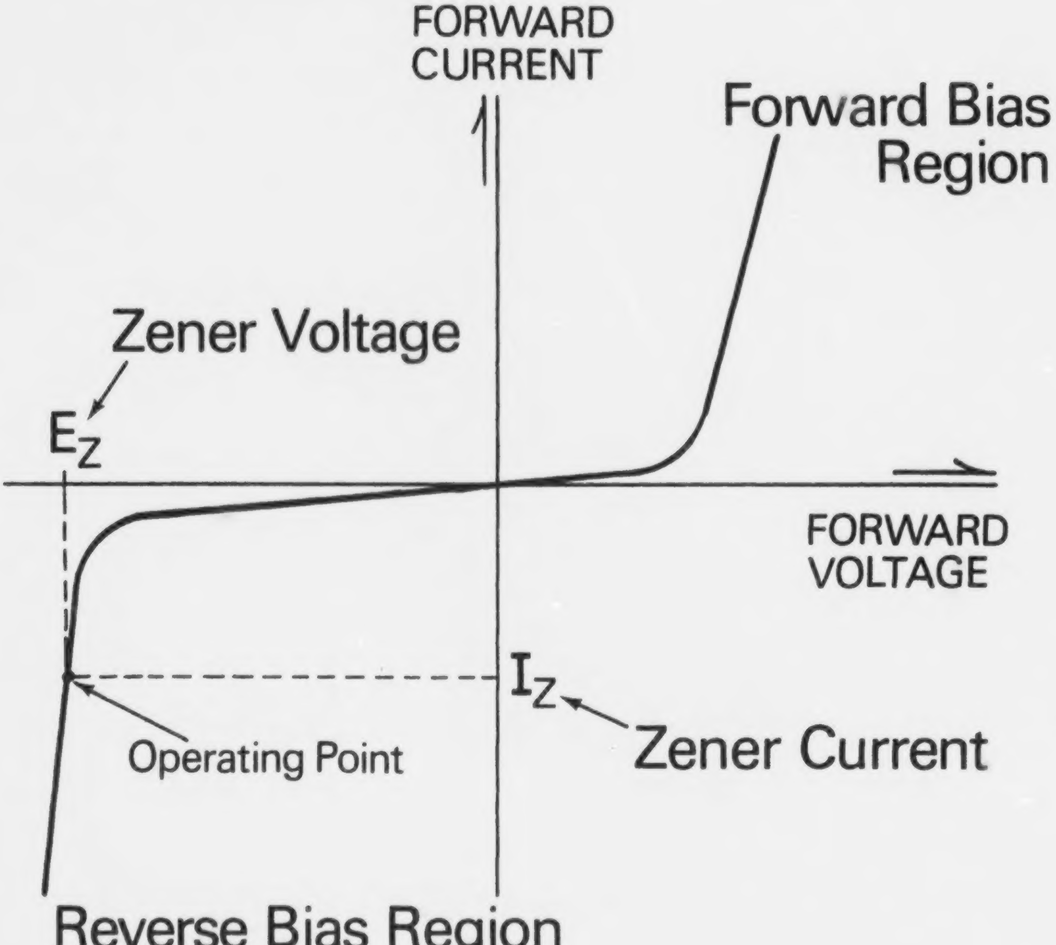
P-N Junction Diode Characteristic Curve


+
(ma) Current
Majority Carriers
PIV
Reverse Bias Region
Voltage
Voltage
Forward Bias Region
Minority Carriers
Current (μa)
Breakdown
–
Anode +
Cathode –
Schematic Symbol

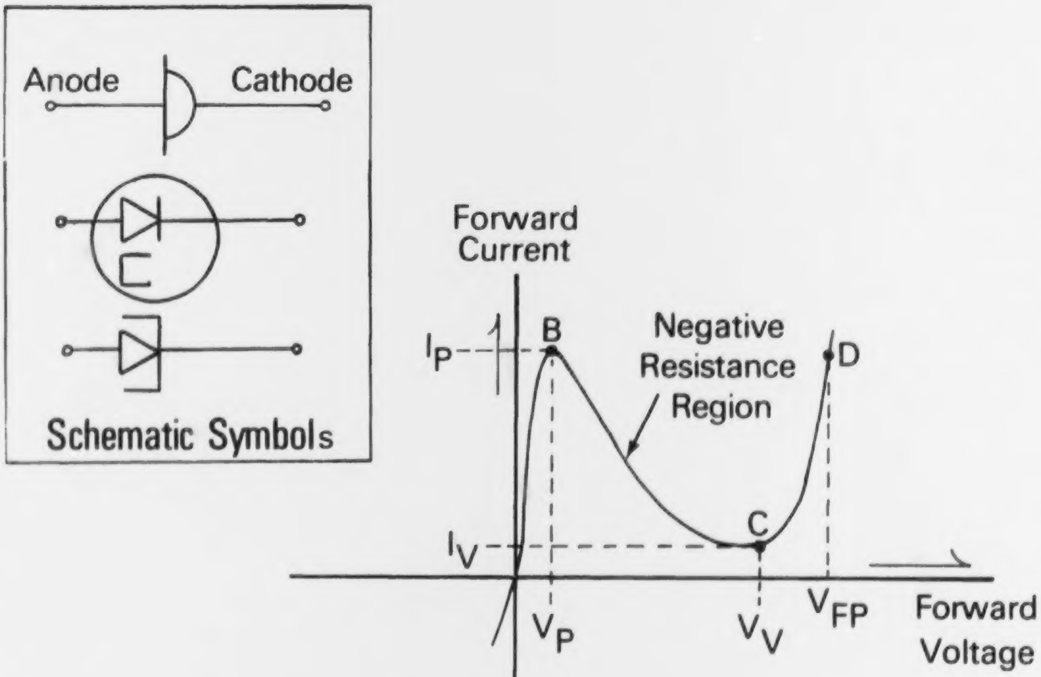
Zener Diode Characteristics



Schematic Symbol



Tunnel Diode Characteristics


Anode
Cathode
Schematic Symbols
Forward Current
I_P
B
Negative Resistance Region
D
C
I_V
V_P
V_V
V_{FP}
Forward Voltage

B – I_P - Peak-Point Current
V_P - Peak-Point Voltage

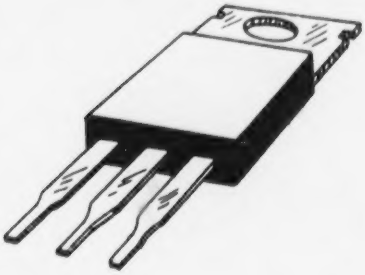
C – I_V - Valley- Point Current
V_V - Valley-Point Voltage

D V_{FP} - Forward-Point Voltage

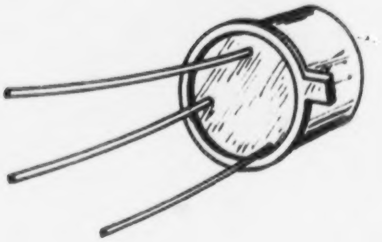
Note:
Negative Resistance Region Exists Between Points B and C

Various Transistor Cases

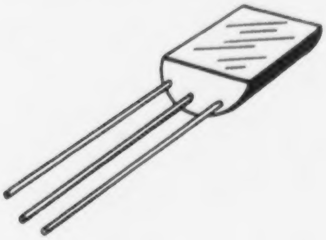
TO-220 Case



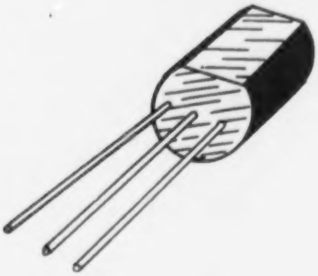
TO-5 Case



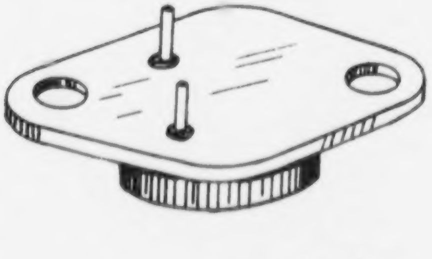
TO-23 Case



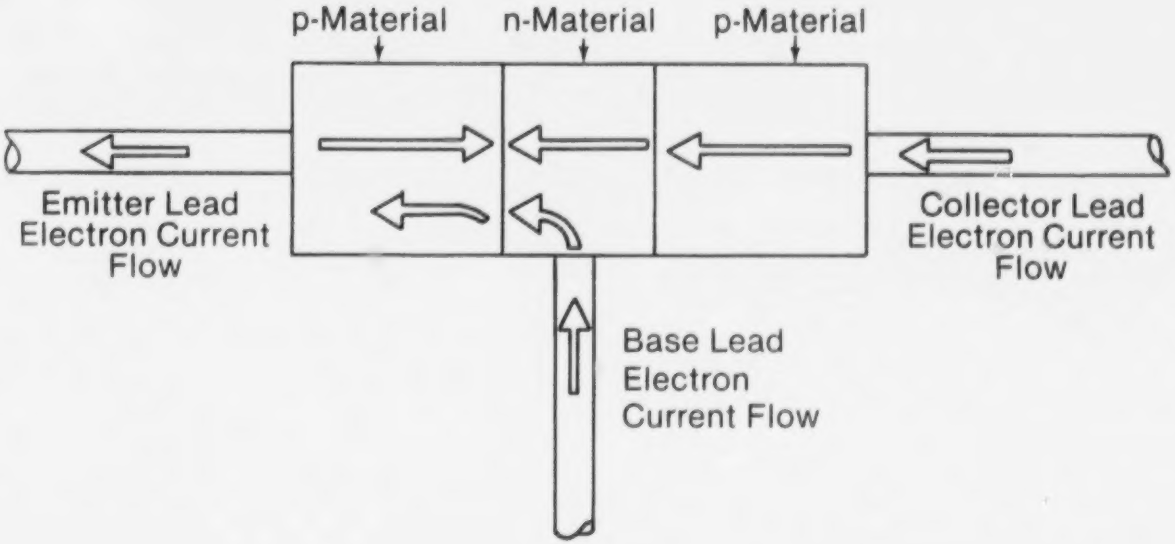
TO-20 Case

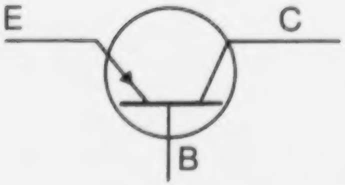


TO-3 Case

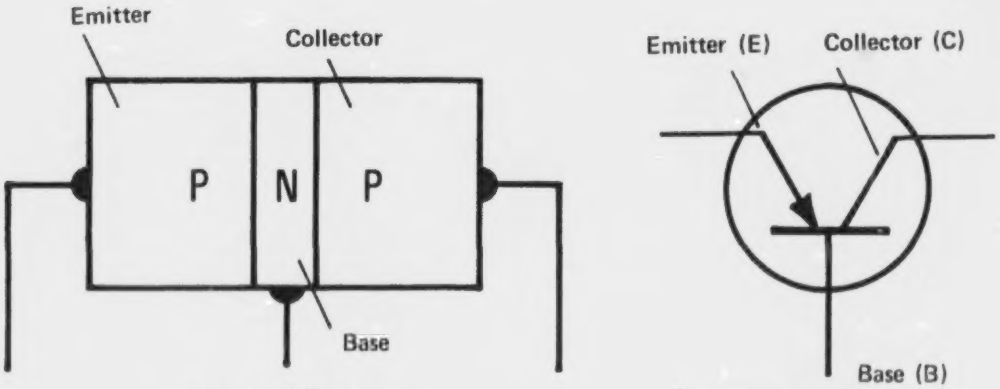


PNP Transistor Majority Current Carriers


p-Material
n-Material
p-Material
Emitter Lead Electron Current Flow
Collector Lead Electron Current Flow
Base Lead Electron Current Flow



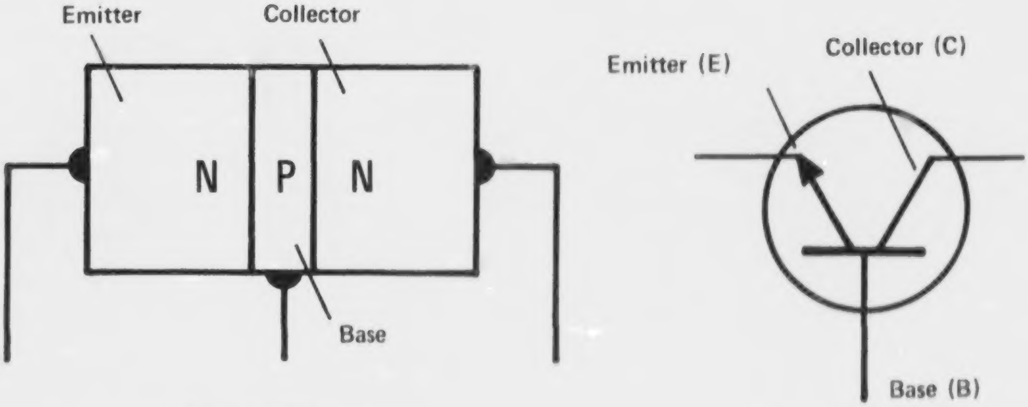
Transistor Block Diagrams and Schematics


Emitter
Collector
P
N
P
Base
Emitter (E)
Collector (C)
Base (B)

Block Diagram

Schematic

PNP Transistor


Emitter
Collector
N
P
N
Base
Emitter (E)
Collector (C)
Base (B)

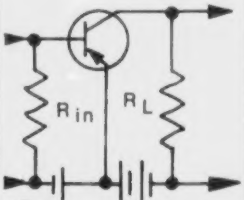
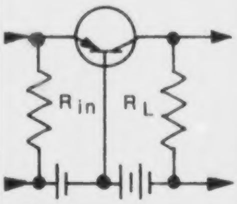
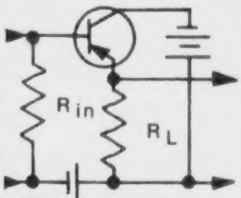
Block Diagram

Schematic

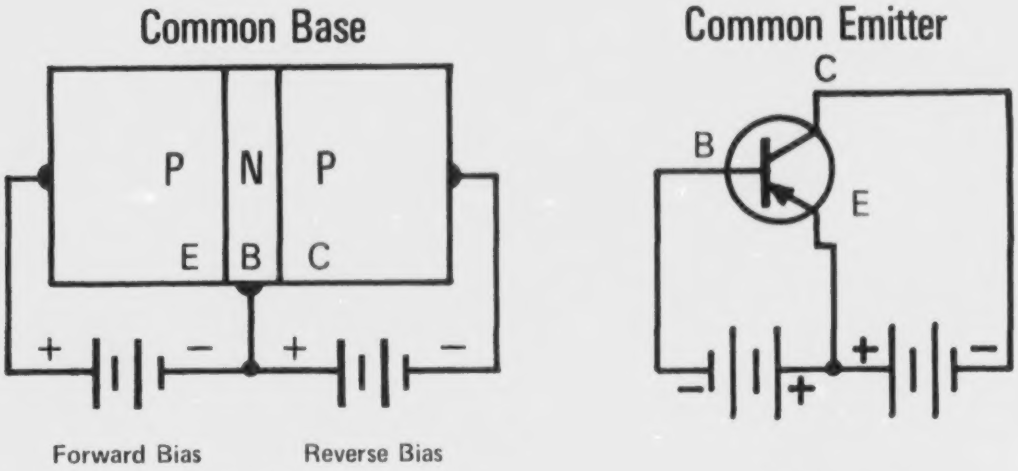
NPN Transistor

(NOTE: In both PNP and NPN transistors, the arrow on the emitter lead points toward the N-type material.)

Comparison of Transistor Circuit Configurations

Characteristics	 Common Emitter	 Common Base	 Common Collector
Voltage Gain $A_e = \frac{E\ out}{E\ in}$	High (300)	High (500)	Low Less Than One
Current Gain $A_i = \frac{I\ in}{I\ out}$	High (50)	Low (0.97)	High (50)
Power Gain $A_p = \frac{P\ out}{P\ in}$	Very High (12,000)	Medium (400)	Low (30)
Input Impedance	Medium (1,000)	Low (60)	High (400,000)
Output Impedance	Medium (50,000)	High (1 M)	Low (100)
Phase Reversal	Yes	No	No

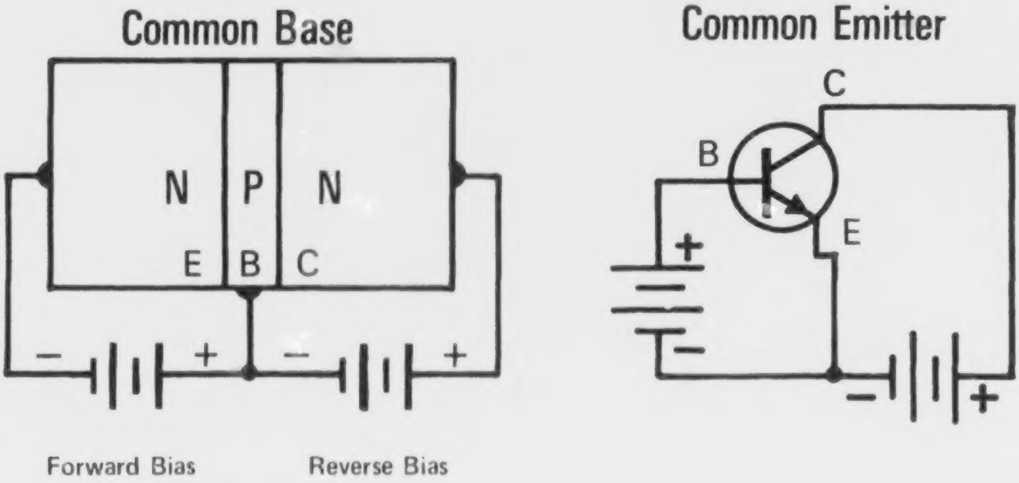
Correctly Biased Transistors


Common Base
P
N
P
E
B
C
+
−
+
−
Forward Bias
Reverse Bias
Common Emitter
C
B
E
−
+
+
−

Block

Schematic

PNP Transistor Bias

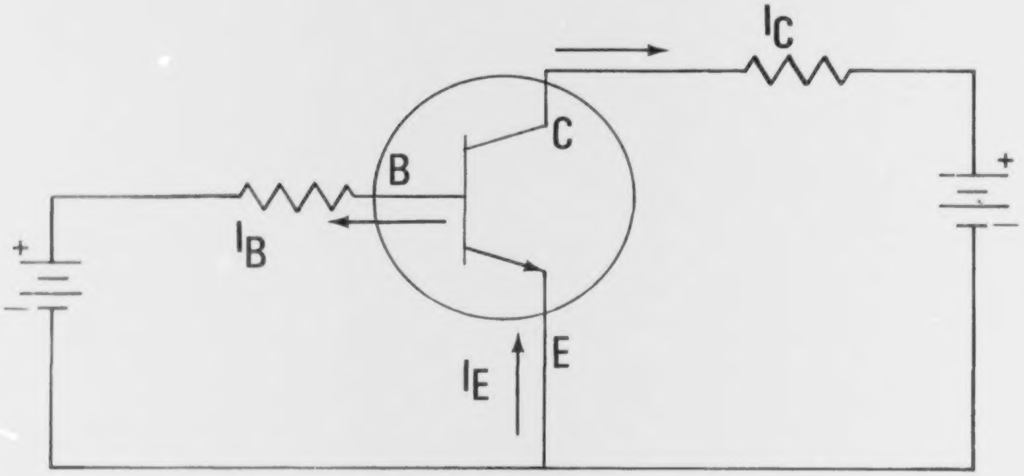

Common Base
N
P
N
E
B
C
−
+
−
+
Forward Bias
Reverse Bias
Common Emitter
C
B
E
+
−
−
+

Block

Schematic

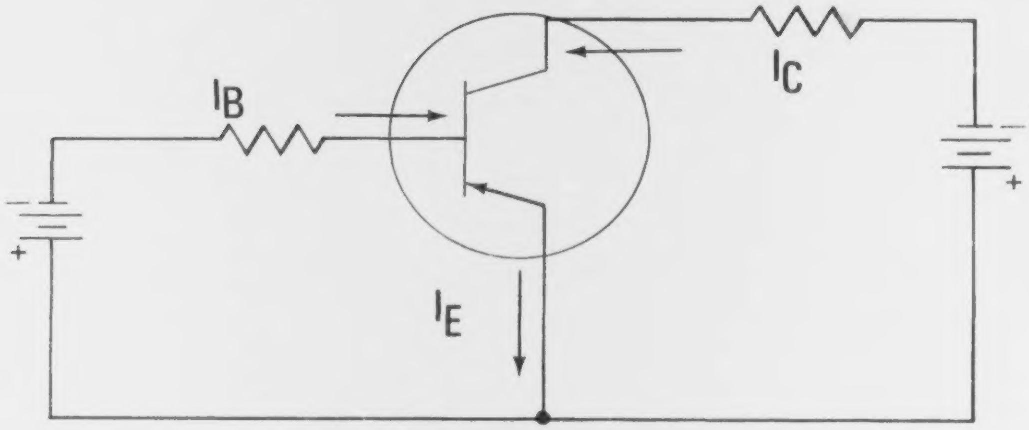
NPN Transistor Bias

Electron Flow in NPN and PNP Transistor Circuits



$I_E = I_B + I_C$

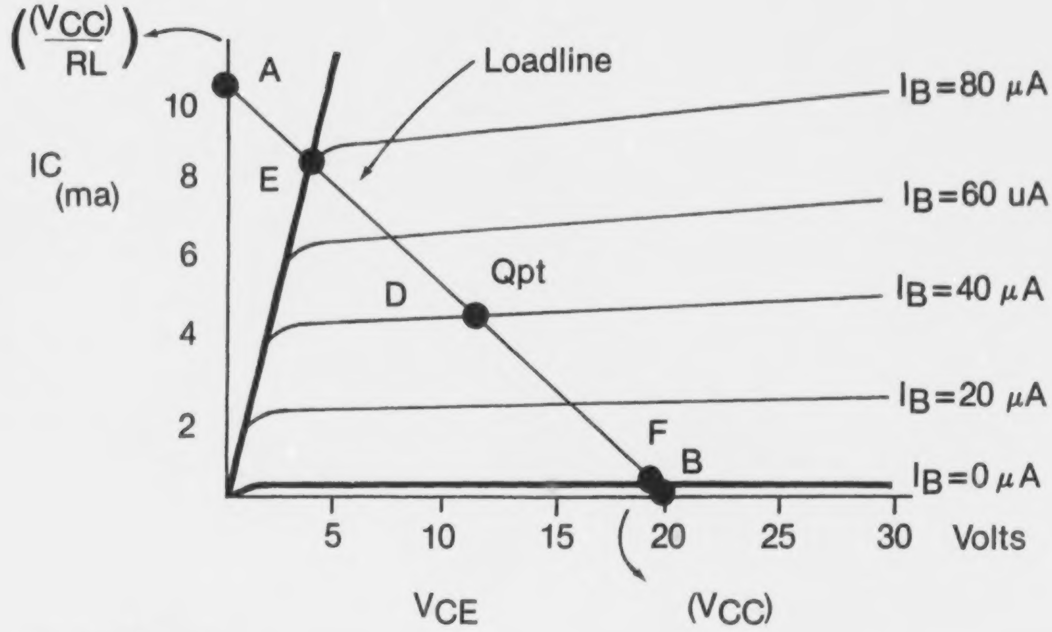
NPN Circuit



$I_E = I_B + I_C$

PNP Circuit

Transistor Load Line



Procedure

A. Locate maximum current point

$$\frac{V_{CC}}{RL} = I\text{max}$$

B. Locate maximum voltage point

$$V_{CE} = V_{CC}$$

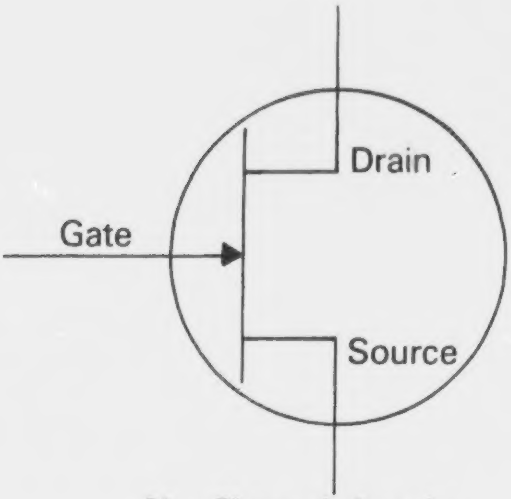
C. Connect these two points with a straight line

D. Locate operating point, Q point, by the intersection of the I B line with the load line

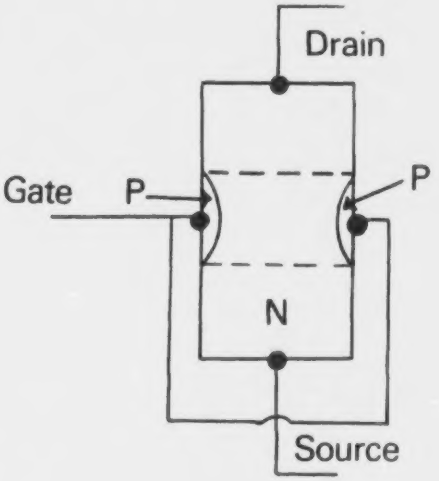
E. Saturation point

F. Cut off point

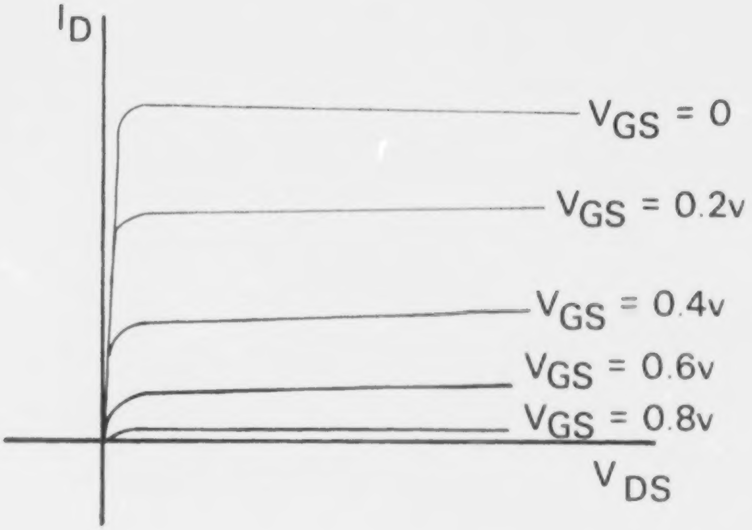
Junction Field-Effect Transistor


Drain
Gate
Source

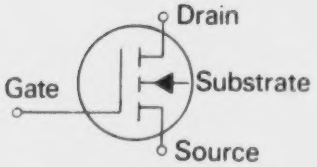
N - Channel Junction
Field Effect Transistor


Drain
Gate
P
P
N
Source

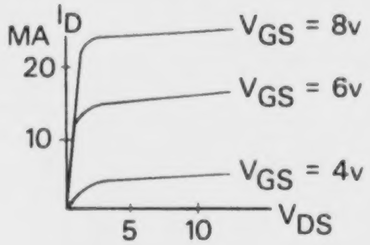
JFET Construction



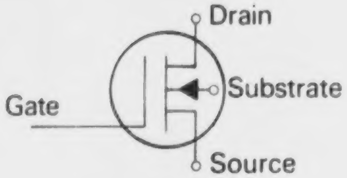
Metal Oxide Semiconductor Field-Effect Transistor


Drain
Gate
Substrate
Source

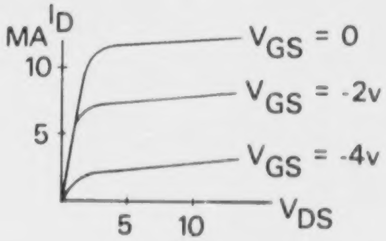
Enhancement Mode
(Type N-Channel)
Schematic Symbol



Output Characteristic Curves

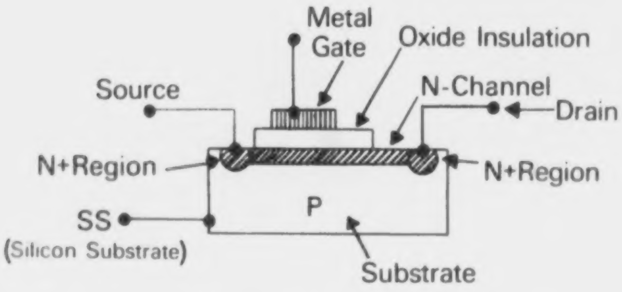

Drain
Gate
Substrate
Source

Depletion Mode
(Type N-Channel)
Schematic Symbol



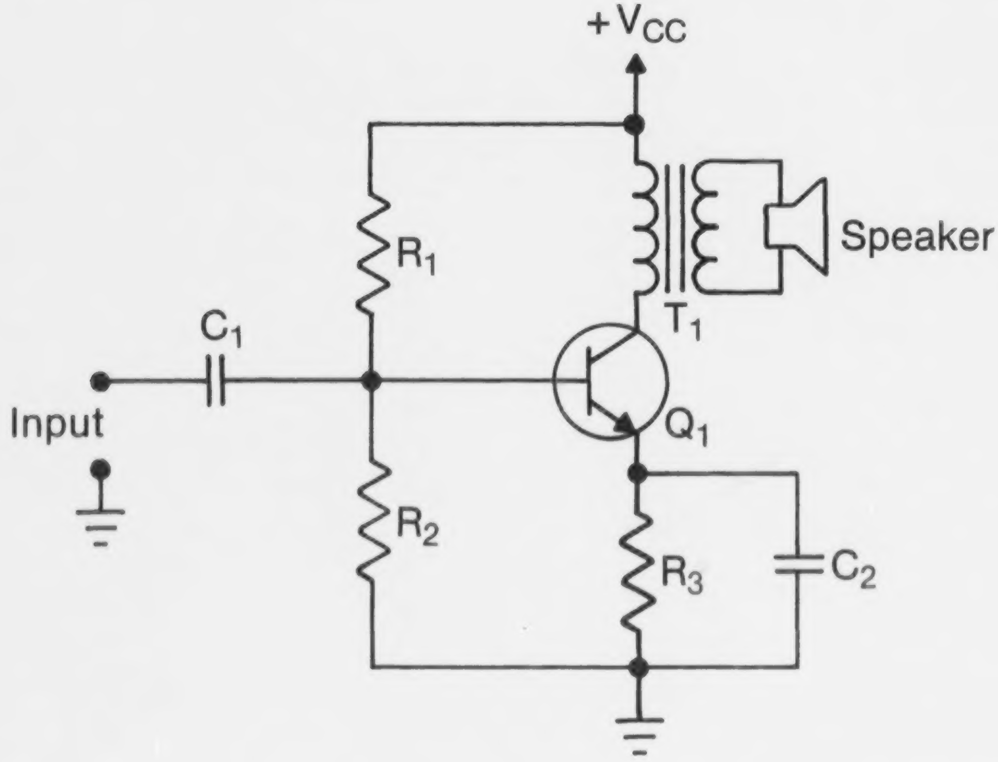
Output Characteristic Curves

Arrow always points toward the N-type material.


Metal Gate
Oxide Insulation
Source
N-Channel
Drain
N+Region
N+Region
P
SS
(Silicon Substrate)
Substrate

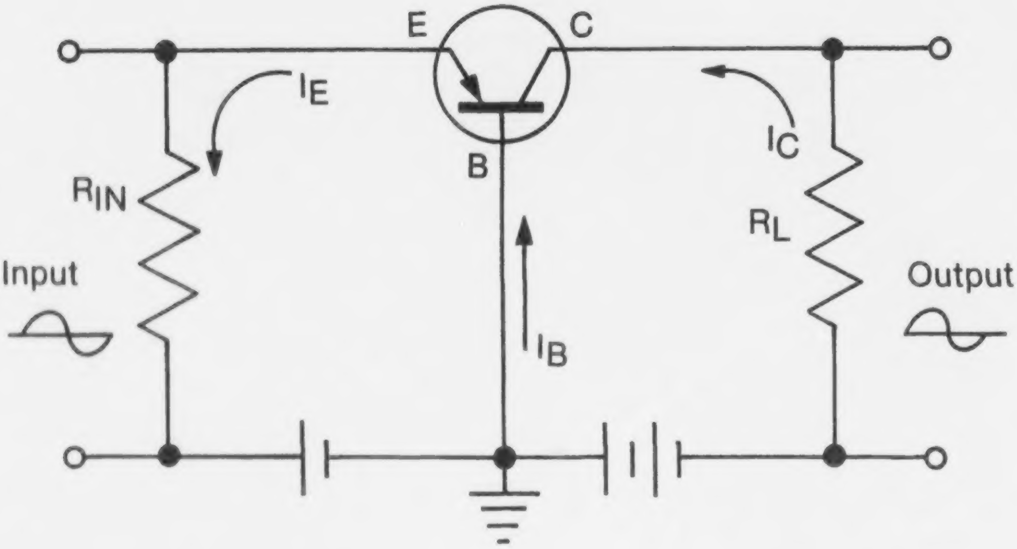
MOSFET Construction – Depletion-Type

Single-Ended Amplifier


+V$_{CC}$
Speaker
R_1
T_1
C_1
Input
Q_1
R_2
R_3
C_2

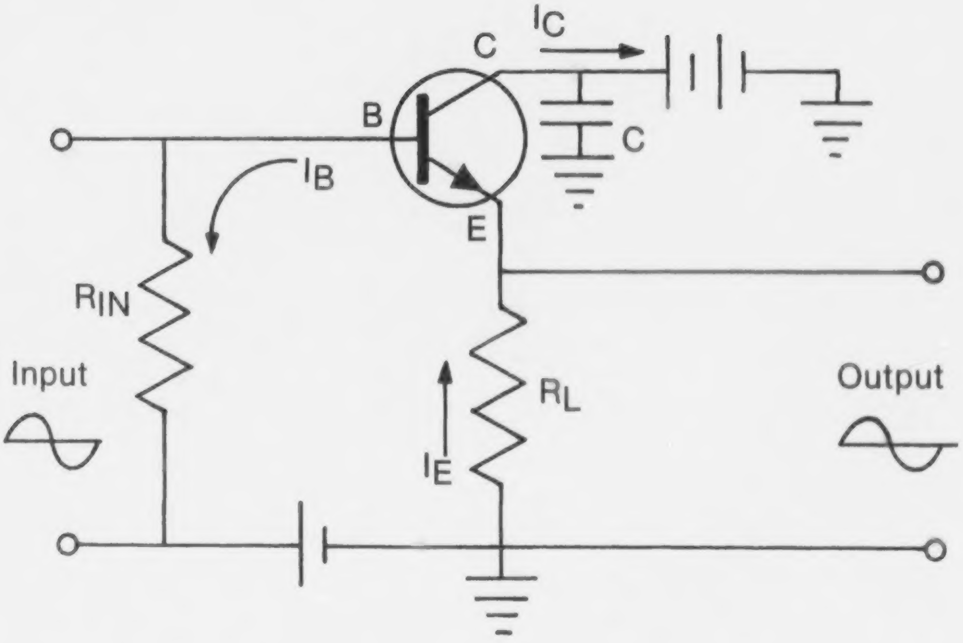
Class “A” Operation

Common-Base (PNP) Amplifier Circuit


E
C
B
I_E
I_C
I_B
R_{IN}
R_L
Input
Output

TM 16

Common-Collector (NPN) Amplifier Circuit

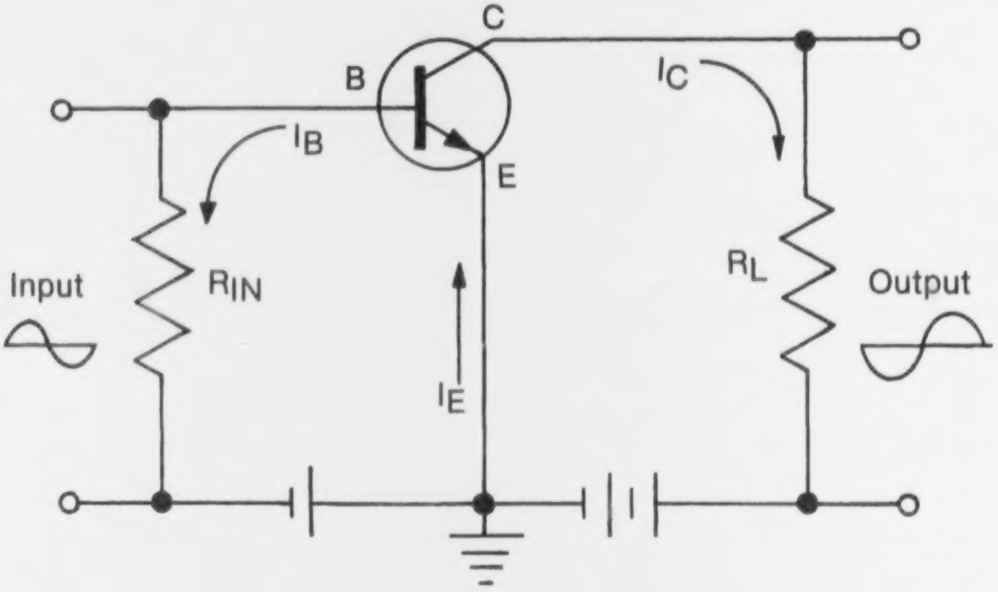


I_C
C
B
C
I_B
E
R_{IN}
Input
R_L
Output
I_E

160

TM 17

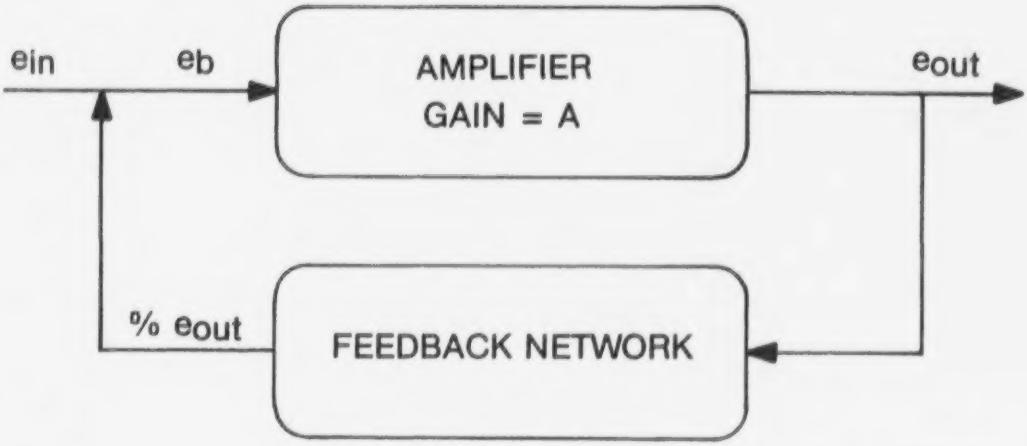
Common-Emitter (NPN) Amplifier Circuit


C
B
I_C
I_B
E
Input
R_{IN}
R_L
Output
I_E

161

TM 18

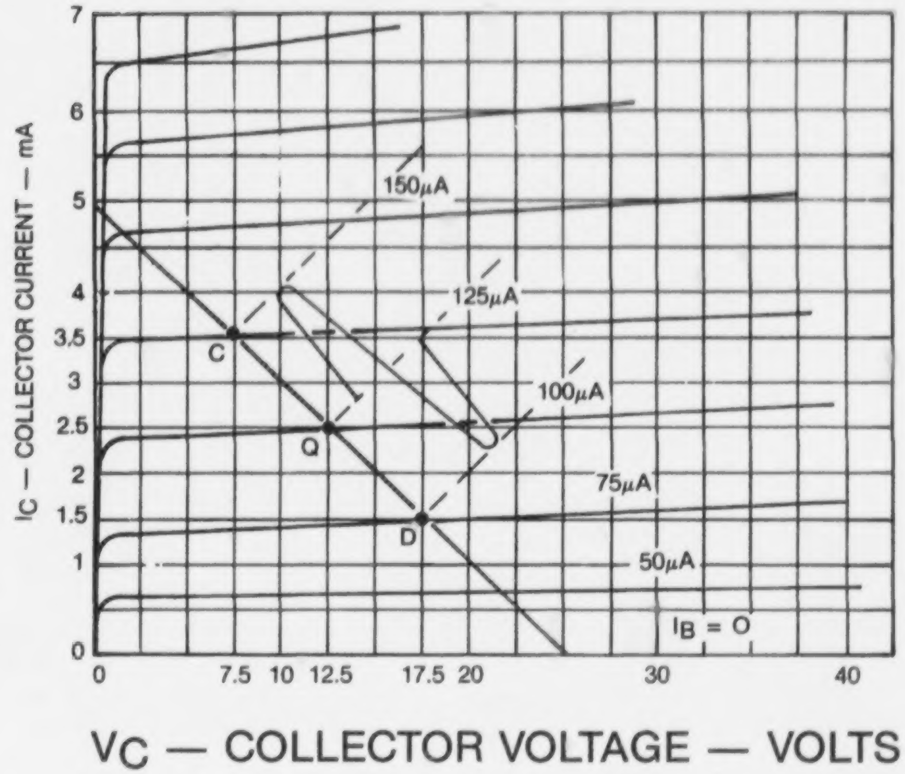
Feedback

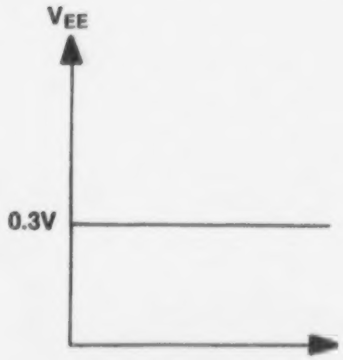

ein
eb
AMPLIFIER
GAIN = A
eout
% eout
FEEDBACK NETWORK

$$e_{in} + \% \, e_{out} = e_b$$

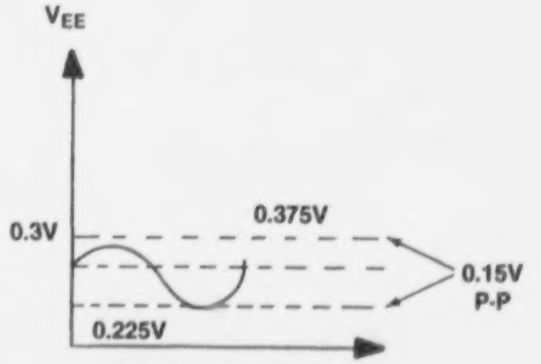
$$A_{FB} = \frac{e_{out}}{e_{in}} = \frac{A}{1 \pm \%} \quad e_{out} \;\; A$$

Load Line for a C-E Amplifier



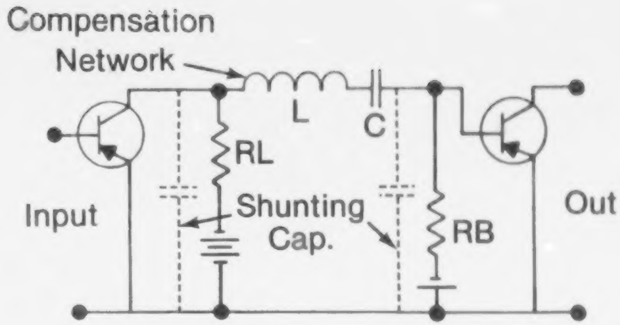


Static Operation
Point Q

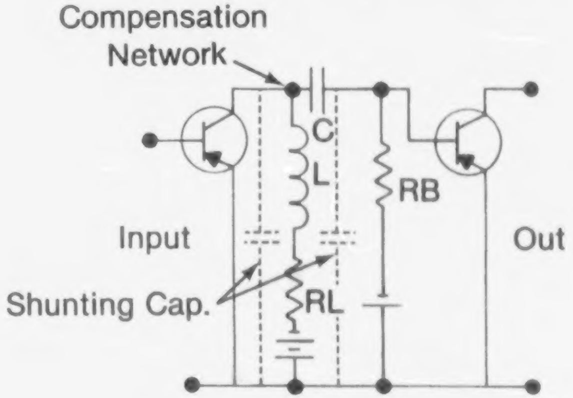

VEE
0.3V
0.375V
0.225V
0.15V
P-P

Resulting Base-Emitter
Voltage

Frequency Compensation Networks

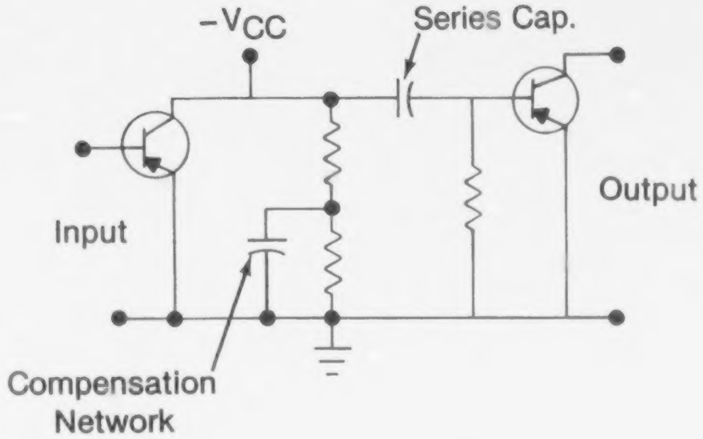

Compensation
Network
L
C
RL
Input
Shunting
Cap.
RB
Out

Series Compensation


Compensation
Network
C
L
RB
Input
Out
Shunting Cap.
RL

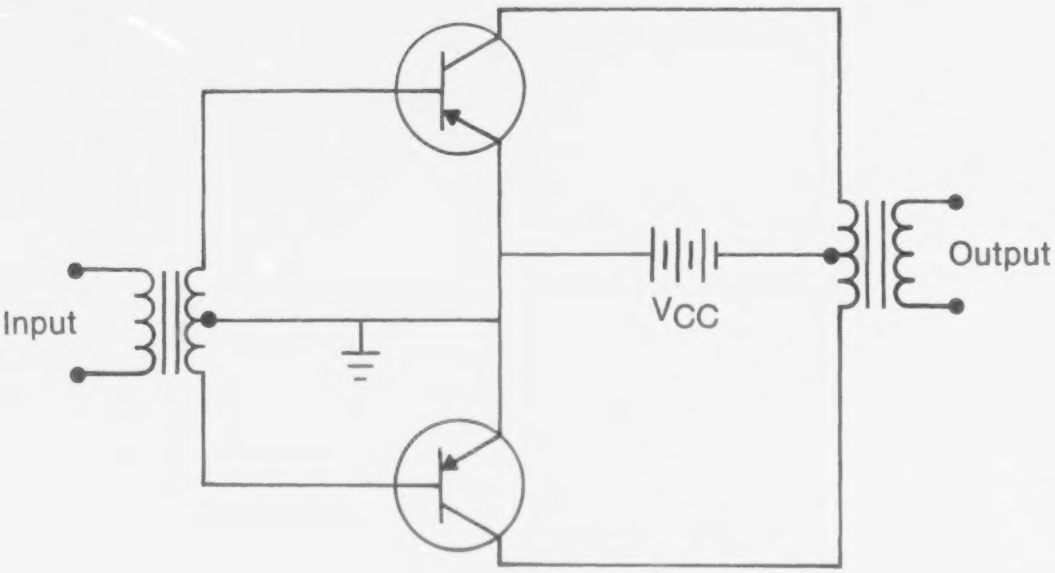
Shunt Compensation

High Frequency Compensation

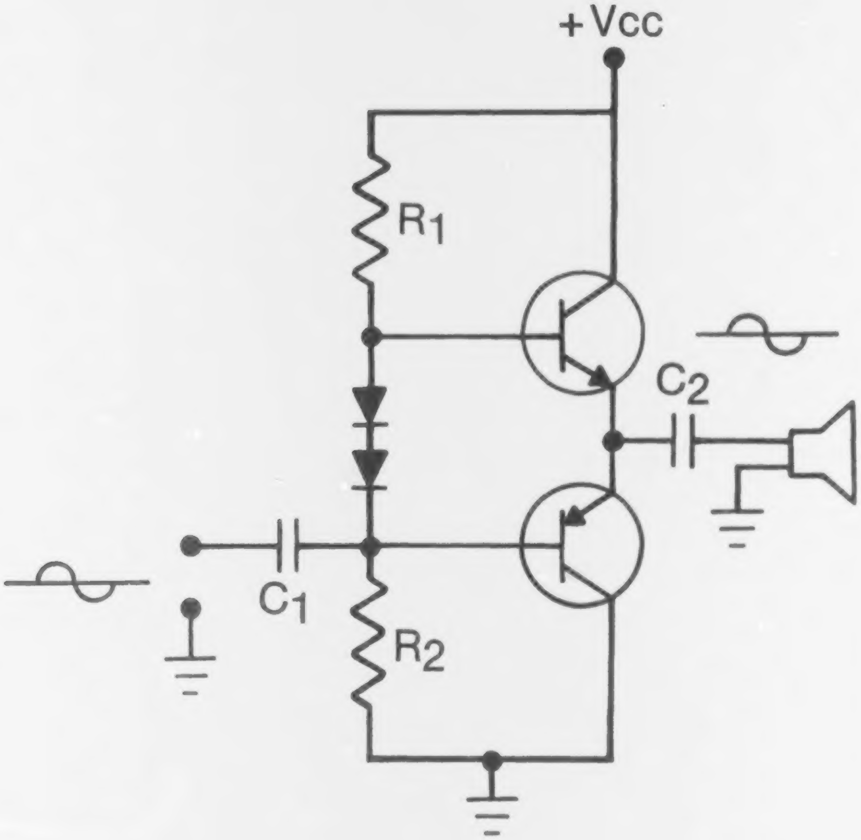

−V_{CC}
Series Cap.
Input
Output
Compensation
Network

Low Frequency Compensation

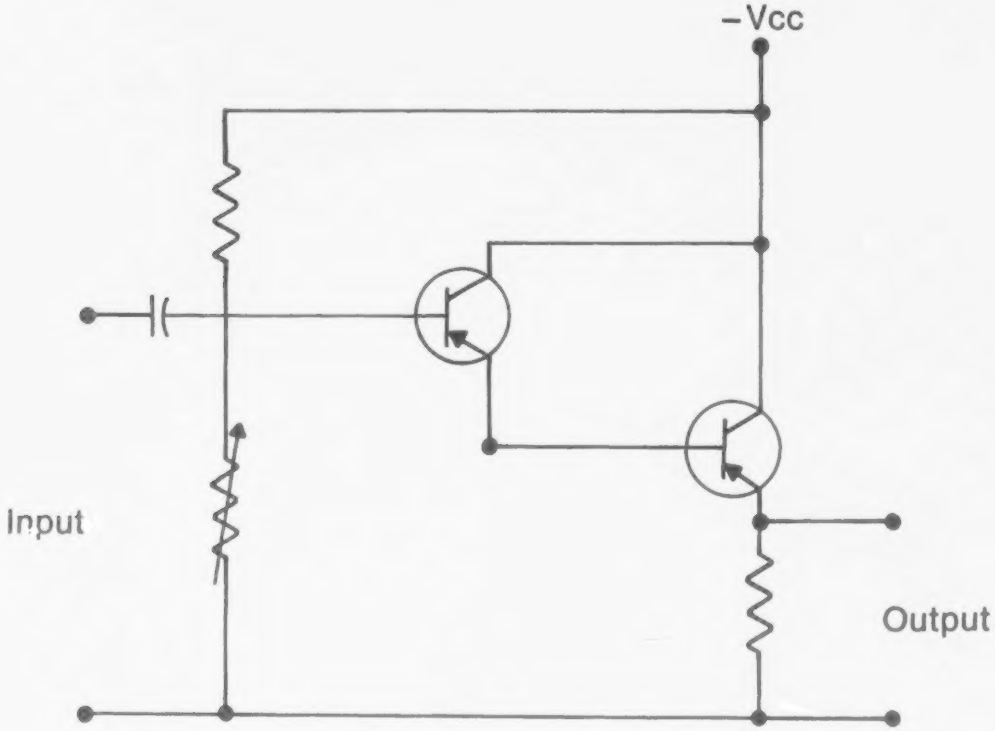
Push-Pull Amplifier


Input
VCC
Output

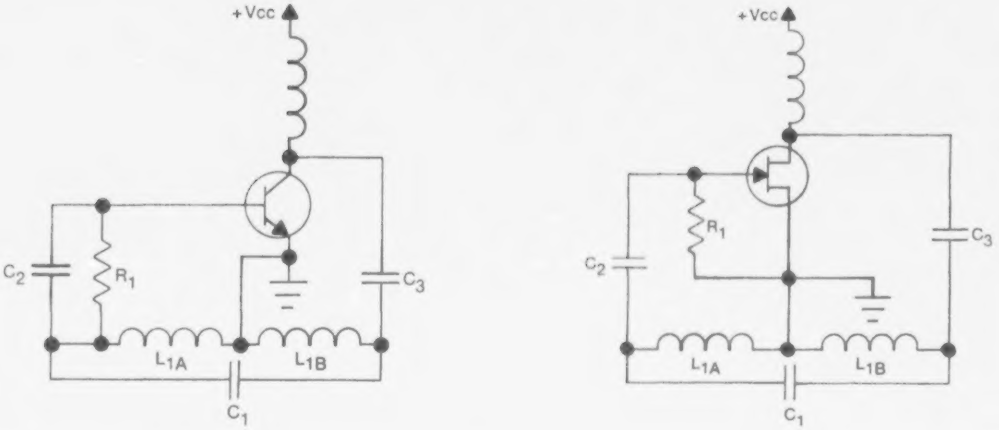
Complementary Symmetry Amplifier



Darlington Pair


–Vcc
Input
Output

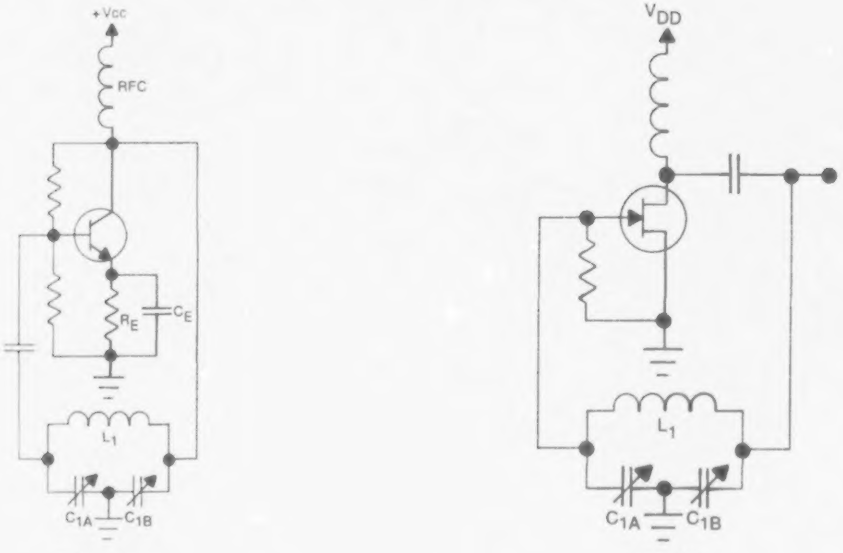
Types of Oscillators


+Vcc
C2
R1
C3
L1A
L1B
C1
+Vcc
R1
C2
C3
L1A
L1B
C1

Bipolar

FET

Hartley


+Vcc
RFC
RE
CE
L1
C1A
C1B
VDD
L1
C1A
C1B

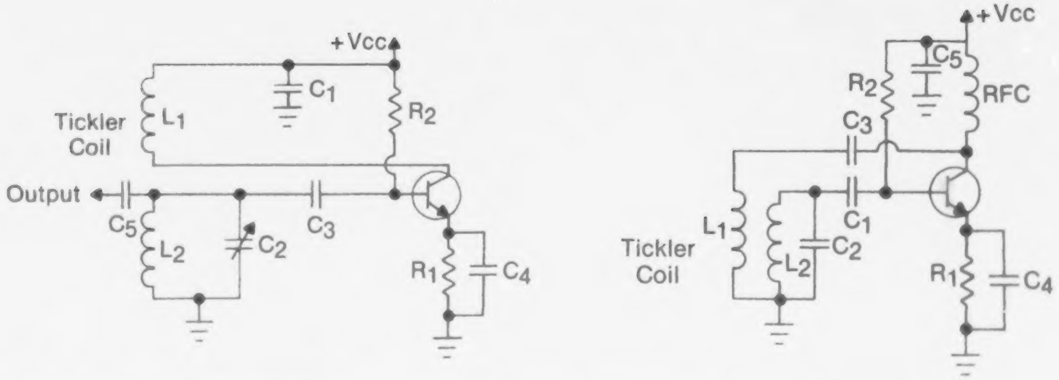
Bipolar

FET

Colpitts

Types of Oscillators

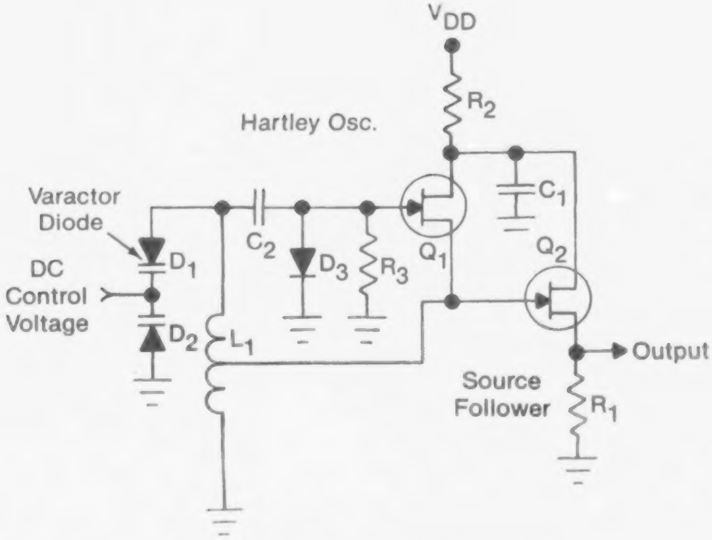
(Continued)


+Vcc
C1
Tickler Coil
L1
R2
Output
C5
L2
C2
C3
R1
C4
+Vcc
C5
R2
RFC
C3
C1
L1
Tickler Coil
L2
C2
R1
C4

Series

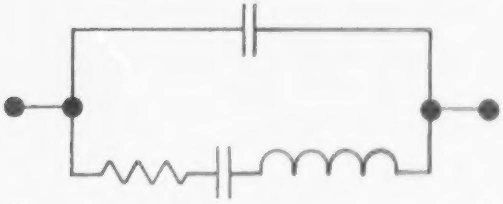
Shunt

Armstrong

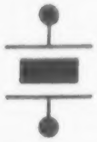

VDD
R2
Hartley Osc.
Varactor Diode
C1
C2
D1
D3
R3
Q1
Q2
DC Control Voltage
D2
L1
Output
Source Follower
R1

Voltage-Controlled
(Hartley shown)

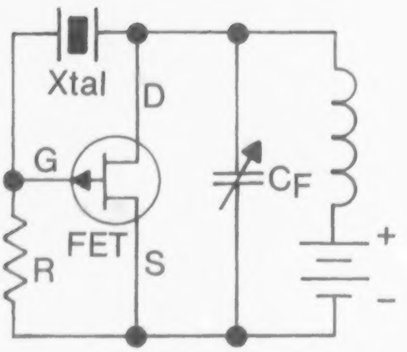
Crystal-Controlled Oscillator



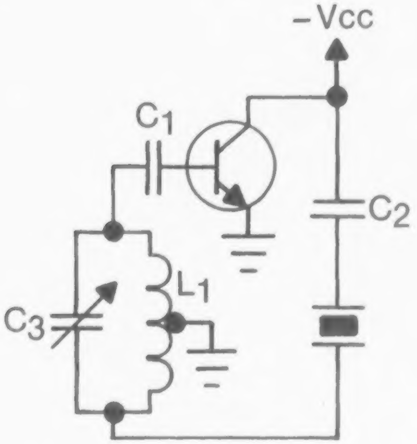
Crystal Equivalent Circuit



Crystal

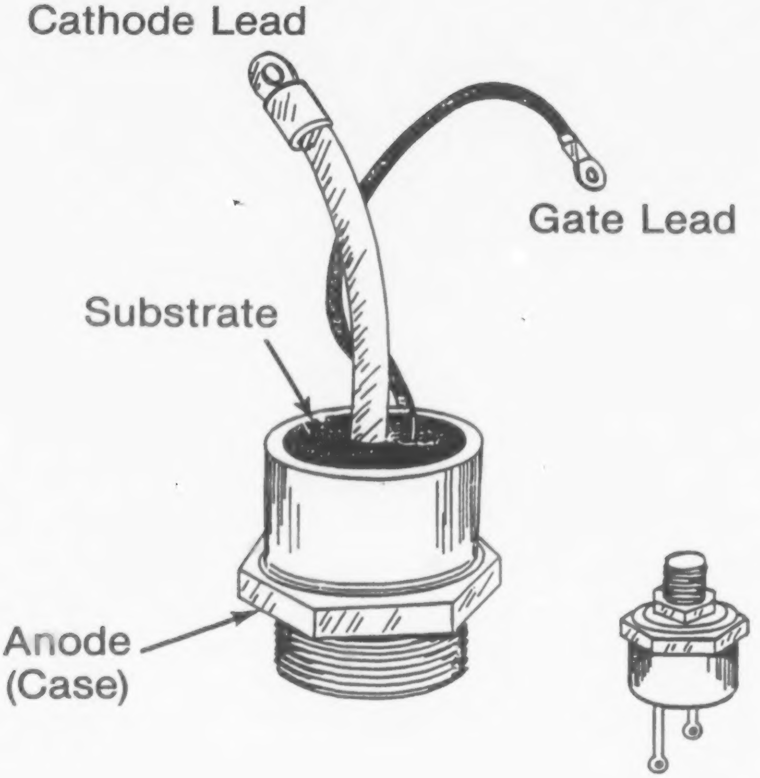

Xtal
D
G
FET
S
R
C_F
+
–

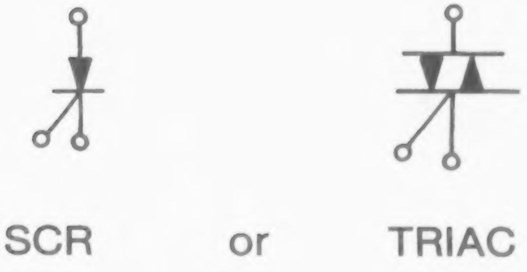
Pierce Oscillator


–Vcc
C_1
C_2
L_1
C_3

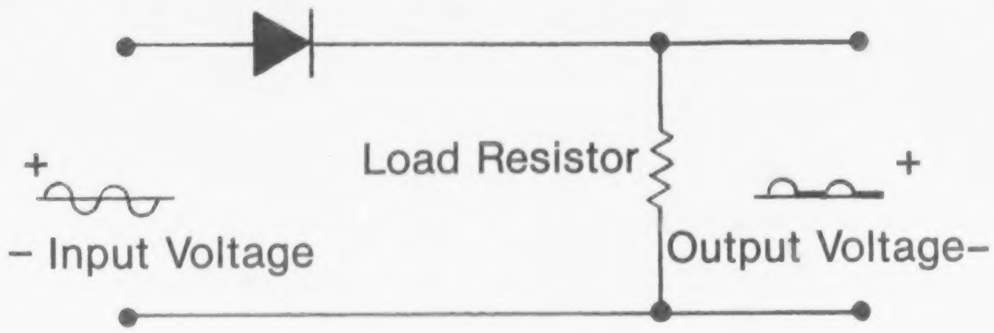
Crystal Controlled Hartley

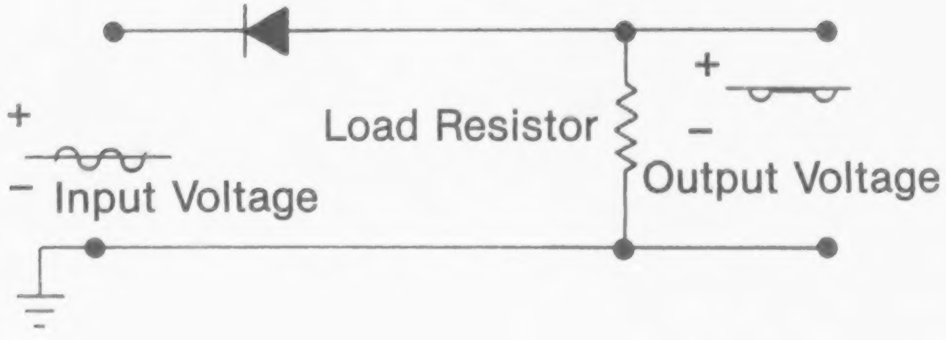
Thyristors


Cathode Lead
Gate Lead
Substrate
Anode
(Case)

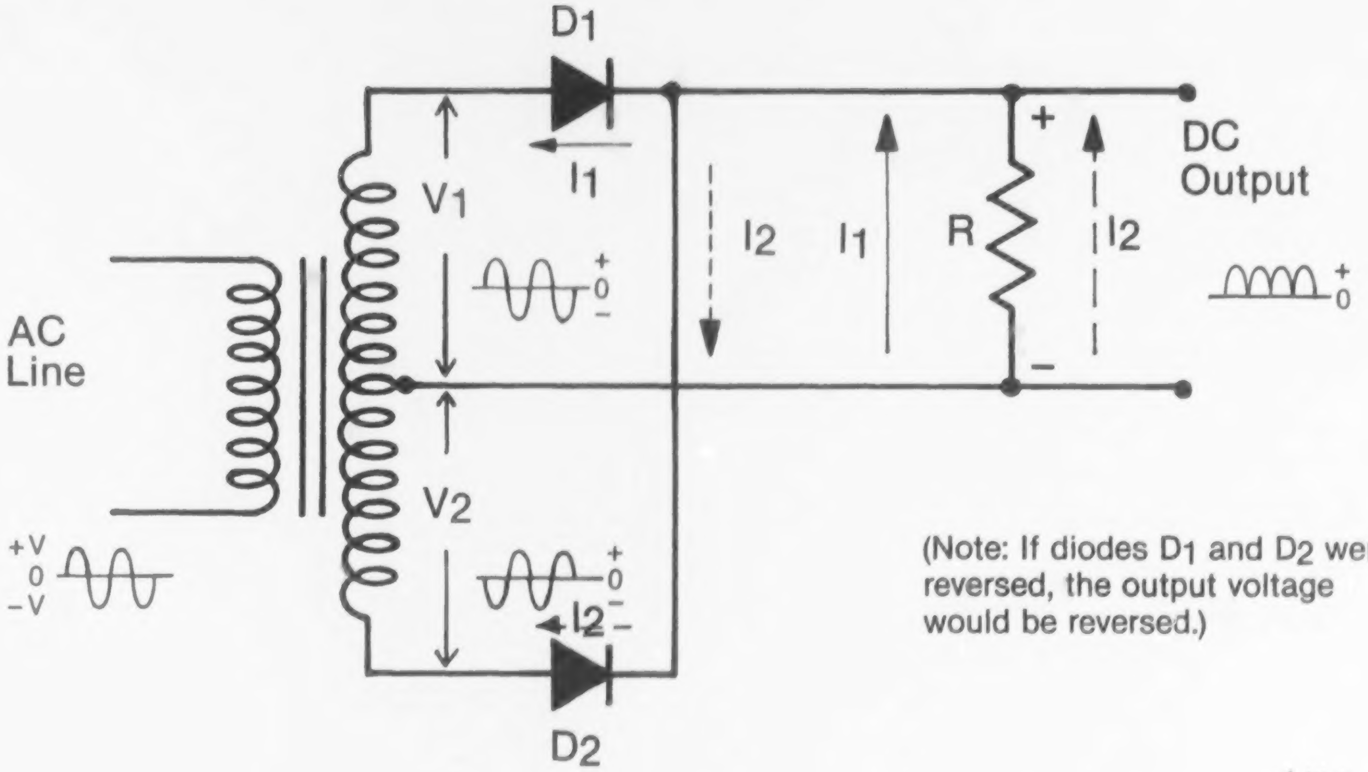

SCR
or
TRIAC

Half-Wave Rectifier Circuits


+
– Input Voltage
Load Resistor
+
Output Voltage–


+
– Input Voltage
Load Resistor
+
–
Output Voltage

Full-Wave Rectifier Circuit

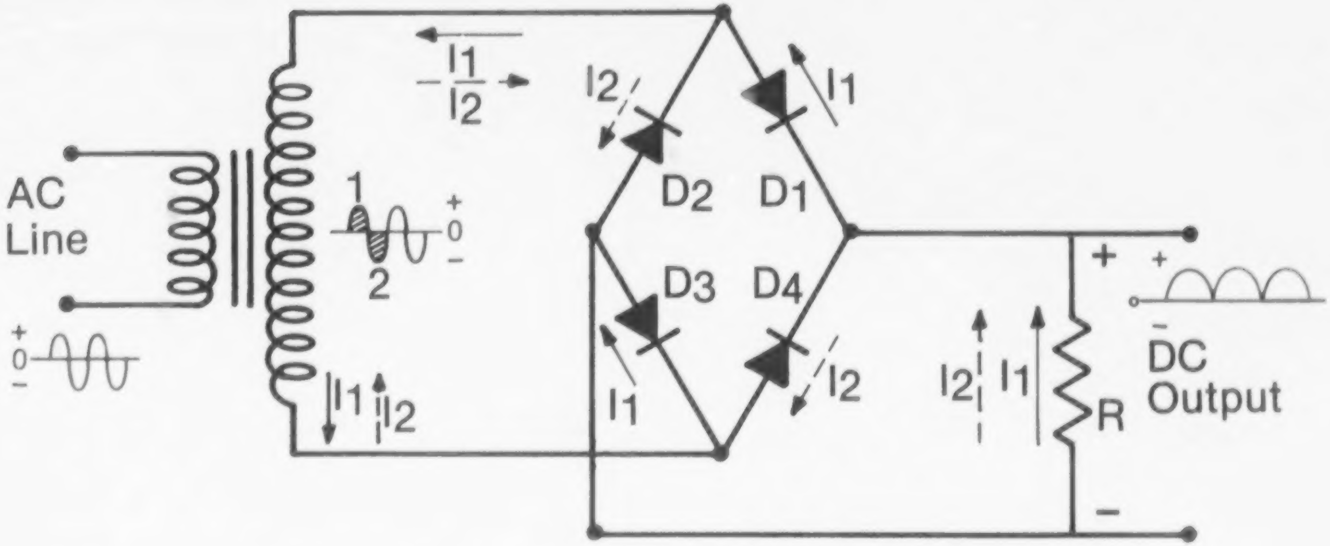

D1
I1
V1
+
0
−
AC
Line
+V
0
−V
V2
+
0
−
I2
D2
I2
I1
R
+
−
I2
DC
Output
+
0

(Note: If diodes D_1 and D_2 were reversed, the output voltage would be reversed.)

General Electronics Technician. Semiconductor Devices and Circuits, Unit 1
Teacher Page 141

TM 30

Full-Wave Bridge Rectifier Circuit



I1
I2
I2
I1
AC
Line
1
2
+
0
–
D2
D1
D3
D4
I1
I2
I1
I2
I2
I1
R
+
–
+
–
DC
Output
+
0
–

(NOTE: If each diode were reversed, the output voltage would be reversed.)

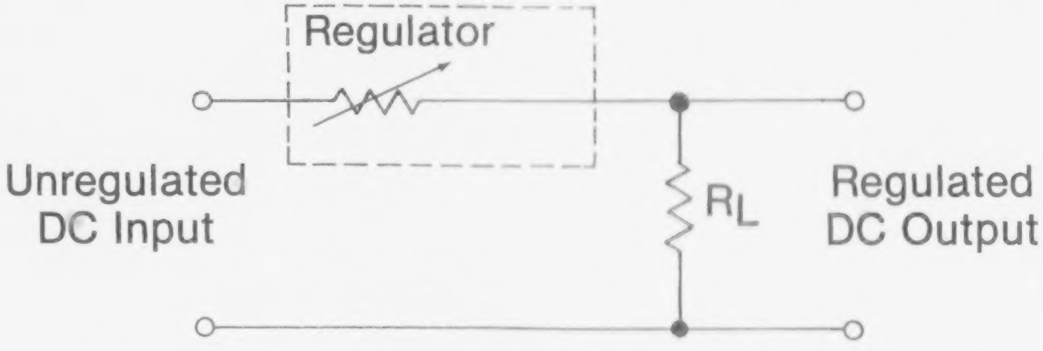
General Electronics Technician, Semiconductor Devices and Circuits, Unit 1
Teacher Page 143

TM 31

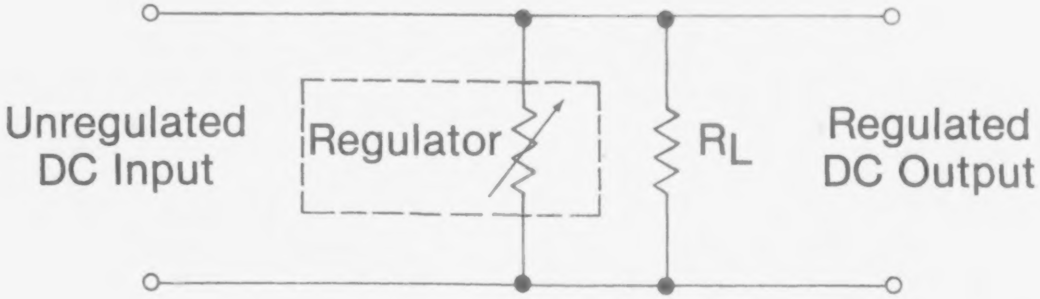
176

177

Voltage Regulation


Regulator
Unregulated
DC Input
RL
Regulated
DC Output

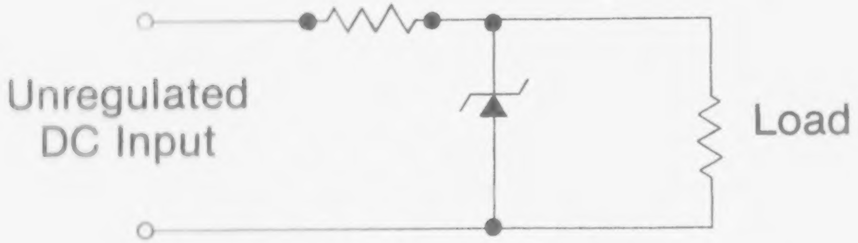
Series Regulation


Unregulated
DC Input
Regulator
RL
Regulated
DC Output

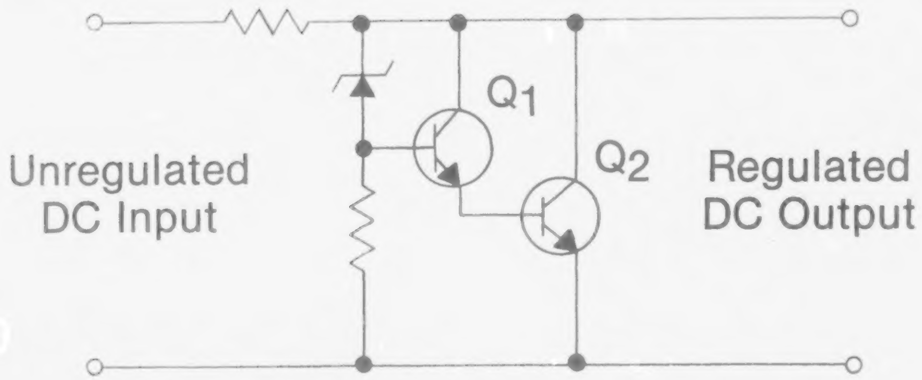
Shunt Regulator

$$\% \text{ Regulation} = \frac{E_{\text{No-Load}} - E_{\text{Full-Load}}}{E_{\text{Full-Load}}} \times 100$$

Zener Diode Regulators

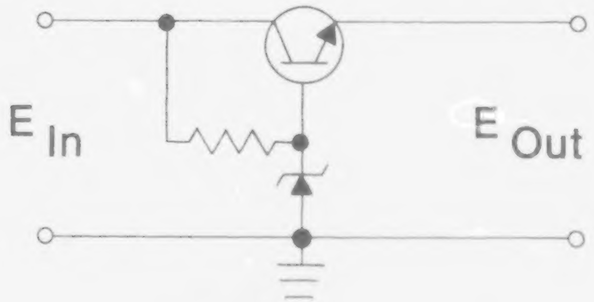

Unregulated
DC Input
Load

Zener Type Shunt Regulator

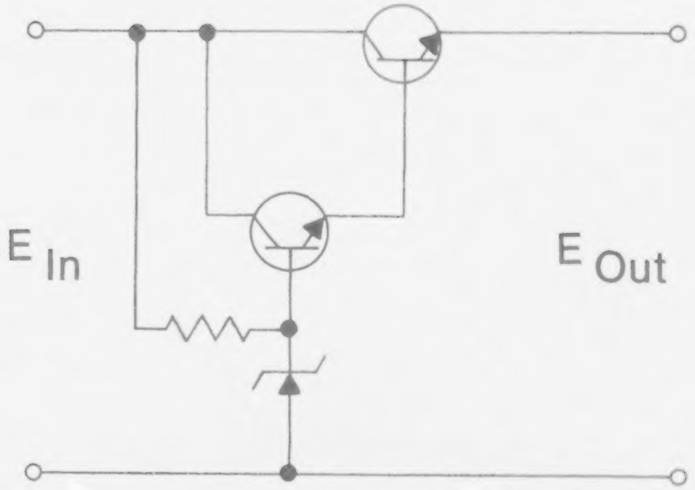

Q1
Q2
Unregulated
DC Input
Regulated
DC Output

Improved Zener Diode Shunt Type Regulator

Series Regulators



Emitter Follower Regulator



Darlington Configuration

Linear Integrated Devices and Circuits
Unit 2

Suggested Activities

Instructional Plan

Preparation

- Review unit and plan presentation. Study the specific objectives to determine the order in which you will present the objectives.

  Review the unit introduction and teaching suggestions included in the delivery and application section below, and plan classroom activities. Also note the suggestions for media and supplemental materials.

  Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.

- Obtain films, videotapes, and other media to supplement instruction of this unit. See ordering information in the suggested resources section.

- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only and should be used with objectives as indicated below.

  TM 1—Categories of Integrated Circuits (Objective 3)
  TM 2—Monolithic Integrated Circuits (Objective 3)
  TM 3—Hybrid Thick-Film Circuit (Objective 3)
  TM 4—Features of a Typical Dual In-Line Package Integrated Circuit (Objective 6)
  TM 5—Basic Differential Amplifier (Objectives 14 and 15)
  TM 6—Single-Input, Single-Output Differential Amplifier (Objectives 14 and 15)
  TM 7—Single-Input, Differential-Output Differential Amplifier (Objectives 14 and 15)
  TM 8—Differential-Input, Differential-Output Differential Amplifier (Objectives 14 and 15)
  TM 9—Operational Amplifier (Objective 16)
  TM 10—Inverting Amplifier (Objective 22)
  TM 11—Noninverting Amplifier (Objective 23)
  TM 12—Gain Vs. Bandwidth (Objective 25)
  TM 13—Two-Input Summing Amplifier (Objective 26)
  TM 14—Four-Input Summing Amplifier (Objective 26)
  TM 15—Differential DC Amplifier (Objective 26)
  TM 16—Hartley Oscillators (Objective 27)
  TM 17—Colpitts Oscillators (Objective 27)
  TM 18—Wein-Bridge Oscillator (Objective 27)

Suggested Activities

TM 19—Simplified Comparator Circuit (Objective 30)
TM 20—Basic Filter Configurations (Objectives 33 and 34)
TM 21—Active Filters (Objectives 33 and 34)
TM 22—AM Transmitter (Objectives 40 and 41)
TM 23—FM Transmitter (Objectives 40 and 41)
TM 24—AM Superheterodyne Receiver Block Diagram (Objectives 40 and 41)
TM 25—FM Broadcast Receiver Block Diagram (Objectives 40 and 41)
TM 26—Modulation (Objective 42)
TM 27—Optical Communications System (Objective 45)
TM 28—Optical Fiber Light Transmission (Objective 46)
TM 29—Loss Factors of Fiber Optic Connectors (Objective 46)
TM 30— Loss Factors of Fiber Optic Connectors (Continued) (Objective 46)
TM 31—Refraction Indices (Objective 46)

- Select teacher components (supplements, written test, unit evaluation form) you want to distribute to your students. Copy and prepare these components for distribution. The supplements included in this unit are designed for use with the objectives as indicated below.

Supplement 1—Report on an Integrated Circuit (Various Objectives)
Supplement 2—Report on a Sensor (Objective 48)

- Prepare classroom. Put up posters and charts and display articles and other references related to the objectives of this unit. Component manufacturers distribute posters of products, characteristic curves, schematics, and other materials that would be useful in supporting this unit. Display products spanning the history of electronics, from vacuum tubes, to discrete semiconductor components, to SSI circuits, to VLSI devices. Try to relate the circuits to each other. For example, if you can display an IC that has extensively more capabilities than displayed circuits of discrete components and early semiconductors.

Delivery and Application

Unit Introduction

- Discuss unit and specific objectives.
- Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

Suggested Activities

- Discuss the assignment sheets and job sheets. Review with students the criteria for evaluation of each of these activities.

Teaching Suggestions

The skill areas appearing in bold-face type in the teaching suggestions refer to the academic and workplace skills identified in *What Work Requires of School: A SCANS Report for America 2000* and *Workplace Basics: The Skills Employers Want*. These have been adapted by MAVCC.

- Display equipment that can show the progress in size, cost, and capabilities achieved through miniaturization. For example, use calculators over the past 30 years or so—starting with an adding machine, early scientific calculators, to today's scientific calculators. Discuss the role of ICs in making space travel and satellite communications possible. Show the students samples of IC cross-sections. Tour an IC manufacturing plant. Invite an electronics engineer to talk to the class about the research going on in ICs and how circuits are designed using ICs. **(Listening; seeing things in the mind's eye; responsibility; materials and resources; career awareness)**

- As you cover each type of IC, display examples of each in a variety of packages and circuits containing those components along with schematics for those circuits—using both commercial and industrial applications. Discuss the role of the subject IC in the circuit. Discuss reasons for choosing that particular component and package for the specific application. Discuss troubleshooting issues and procedures for the component and the applications. As you continue through the unit, reduce the amount that you lecture and demonstrate on these subjects and shift the responsibilities to the students. Use data sheets and the supplements to have the students make reports to the class about the latest advances in ICs and to expand the class's knowledge base about the devices being studied. **(Listening; reading; writing; speaking; acquiring, organizing, interpreting, and processing information; science; applying technology; adapting to the organization's goals and values)**

- As you cover the IC applications in this unit, display circuits, schematics, troubleshooting charts, and other resources to supplement the discussions. Demonstrate actual applications and relate them to larger systems. Review the interrelationship of the applications, such as amplifiers and oscillators. Use the supplements to have the students report on innovations in such applications. Relate ICs to circuits that they studied in previous units, including the first book in this series. One approach is to discuss the Darlington connection, show a Darlington transistor, and then show an IC that incorporates Darlington pairs. Get the students to think about the electronics in their everyday lives and speculate as to the use of amplifiers, oscillators, rectifiers, etc. in those devices. **(Listening; reading; writing; speaking; acquiring, organizing, interpreting, and processing information; science; applying technology; adapting to the organization's goals and values; system interrelationships)**

- Discuss standard IC packages, marking, and standardized numbering systems. Help the students understand pin identification and how these pins relate to electrical and electronic concepts that they have studied previously, such as the supply circuits in op-amps, impedance matching, etc. Help the students understand how to interpret the way data is presented in specification tables, characteristic curves, waveform illustrations, etc. Use such technical data and demonstrations to expand on concepts such as noise, signal-to-noise ratio, crossover distortion, etc. Also relate oscilloscope displays and equipment performance (such as the sound from speakers and graphic analyzer displays) to distortion and to concepts that appear on data sheets, such as breakover voltage, PIV, and breakdown voltage. **(Listening; reasoning; applying technology; adapting to the organization's goals and values; seeing things with the mind's eye)**

- Tour your facility or other facilities such as manufacturing plants to see sensor and actuator circuits in action. Tour a radio station to see the electronics related to RF and IF objectives. Visit a wireless or satellite communications center or have a resource person from such a company talk about microwave applications and uses in your area in particular. Visit a telephone company or facility with extensive internal fiber optic networks to see such systems in use. Provide samples of microwave ICs, fiber optic devices, and similar hardware for the students to study. **(Listening; reasoning; applying technology; adapting to the organization's goals and values; seeing things with the mind's eye; career awareness; system interrelationships; materials and facilities)**

- The first two assignment sheets in this unit lend themselves especially well to be supplemented with the use of actual components and systems. For example, operate inverting and noninverting circuits. Use an oscilloscope to show the phase relationships between the input and output signals. Measure feedback voltages and show how they can be regenerative or degenerative. **(Listening; seeing things in the mind's eye; adapting to the organization's goals and values; problem-solving; arithmetic/mathematics; reasoning; interpreting information)**

Evaluation

- Discuss with students the use of the Unit Evaluation Form. Explain the rating scale that will be used for student evaluation.
- Copy written test and give to students as pretest. Record pretest score on the Unit Evaluation Form.
- Evaluate assignment sheets. See the evaluation criteria listed at the top of each assignment sheet and the component "Answers to Assignment Sheets."
- Evaluate job sheets. See the evaluation criteria listed at the top of each job sheet.
- Give and evaluate written test.
- Compile written-test, assignment-sheet, and job sheet scores on the Unit Evaluation Form. Include any additional assignments.
- Measure competency gains by comparing written pretest scores with posttest scores.
- Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.
- Reteach and retest as required.

Instructions for Evaluating Student Performance

- When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job

Suggested Activities

sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 — Skilled—Can perform job with no additional training.
3 — Moderately skilled—Has performed job during training program; limited additional training may be required.
2 — Limited skill—Has performed job during training program; additional training is required to develop skill.
1 — Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Suggested Resources

Resources Used in Developing This Unit

- *Basic Electronics.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1987.
- *Communications Electronics.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1988.
- Davidson, Homer L. *Electronic Troubleshooting and Repair Handbook.* New York: McGraw-Hill, 1995.
- Davidson, Homer L. *Troubleshooting and Repairing Compact Disc Players.* 2nd Ed. New York, New York: TAB Books, 1994.
- *General Electronics Technician.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1987.
- *Graphic Symbols for Electrical and Electronics Diagrams.* New York: Institute of Electrical and Electronics Engineers, Inc., 1975.
- *Home Electronics.* Alexandria, Virginia: Time-Life Books, 1988.
- McMenamin, J. Michael. *Applied Electronic Devices and Analog ICs.* Albany, New York: Delmar Publishing, Inc., 1995.

Suggested Activities

- Newby, Bruce. *Electronic Signal Conditioning.* Oxford, England: Butterworth-Heinemann Ltd., 1994.

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- Roehrig, Guido and Ulrich Schueller. *Upgrading and Maintaining Your PC.* Grand Rapids, Michigan: Abacus, 1991.

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- Simpson, Colin D. *Principles of Electronics.* Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1996.

- Villanucci, Robert S., Alexander W. Avtgis, and William F. Megow. *Electronics Techniques: Shop Practices and Construction.* 5th Edition. Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1996.

Supplemental Resources

Print Media

- *The Chip: How Two Americans Invented the Microchip and Launched a Revolution*, by T. R. Reid (Simon and Schuster, 1984). This is a very readable book that gives good insight into the lives and work of Jack Kilby at Texas Instruments and Robert Noyce in the area that would become known as the Silicon Valley. The device that they pioneered independently has changed the world. This book tells how the discoveries came about, covers what happened to these two very different men in the wake of their discoveries, and explores issues such as why everyone in America does not know Kilby and Noyce the way they know Thomas Edison and Alexander Bell. Most electronics students should enjoy this book. It is not overloaded with technology yet should help students feel good about their chosen profession and give hope that one person can still make major contributions.

- Data sheets for applicable semiconductor devices. Available from manufacturers and in handbooks.

- Schematics for circuits discussed in conjunction with this unit. Available from equipment manufacturers.

Suggested Activities

Non-print Media

- *CMOS and ECL ICs.* This 1989 program is useful as an explanation of the functioning of devices in these two families of logic. However, some of the material would be better suited for the next book in this series. Available from: Tel-A-Train; P.O. Box 4752; Chattanooga, TN 37405; 800-266-0113.
- *Counters.* Covers the design and operation of counters. Available from: Tel-A-Train; P.O. Box 4752; Chattanooga, TN 37405; 800-266-0113.
- *Introduction to Integrated Circuits.* Basic information about the design, manufacture, advantages, and other features of ICs. Available from: Texas Instruments Learning Center; Mail Station 54; P.O. Box 225012; Dallas, TX 75265.
- *Introduction to VLSI Design Series.* This series of programs is intended for engineering students and much of the information is beyond the scope of this course. However, some of the programs deal with basic principles and types of ICs and could be used with this unit of instruction. Available from: Massachusetts Institute of Technology; Video Courses CEC; 77 Massachusetts Ave.; Cambridge, MA 02139.
- *Linear IC Technology.* Discusses the materials used in IC production, performance specifications, and related information. Available from: Texas Instruments Learning Center; Mail Station 54; P.O. Box 225012; Dallas, TX 75265.
- *Microchip Technology.* Basic information about ICs, how they are made, and how they work. Available from: Bergwall Productions, Inc.; P.O. Box 238; Garden City, NY 11530-0238; 800-645-3565.
- *The Sub-Micron Challenge.* Discusses miniaturization, emphasizing large-scale and very large-scale integration. Available from: The Japanese Institute for Social and Economic Affairs, Charles Von Loewenfeldt, Inc., 1333 Gough St., San Francisco, CA 94109.

Linear Integrated Devices and Circuits
Unit 2

Answers to Assignment Sheets

Assignment Sheet 1—Calculate the Closed-Loop Gain for an Inverting and a Noninverting Amplifier

1. -10
2. -50 volts
3. -50
4. +20 volts
5. -30
6. 9
7. 1.8 volts
8. 126
9. 0.5 volts
10. 21

Assignment Sheet 2—Calculate the Output Voltage of a DC Summing Amplifier

1. -10 volts
2. -18 volts
3. 2 volts
4. 40 volts
5. -1.9 volts
6. 45 volts
7. 16 volts
8. -15 volts
9. 1.5 volts
10. 3.2 volts

Assignment Sheet 3—Determine Specifications for Commercially Available Op-Amps

Evaluated to the satisfaction of the instructor using the criteria given in the assignment sheet.

Linear Integrated Devices and Circuits
Unit 2

Answers to Written Test

1.

a.	20	g.	2	m.	15	s.	24
b.	5	h.	10	n.	9	t.	13
c.	7	i.	21	o.	16	u.	23
d.	14	j.	4	p.	19	v.	17
e.	8	k.	3	q.	12	w.	1
f.	11	l.	6	r.	18	x.	22

2. a. P
   b. A

3. a. 3
   b. 4
   c. 2
   d. 1

4. a. Material
   b. Package design
   c. Pin design

5. a. Prefix—Generally one to three letters that identify the type of device or family of devices
   b. Part number—Three- or four-digit number that is assigned to the specific functionality of the device
   c. Suffix—Various combinations of letters and symbols that have specific meanings regarding packaging, performance, reliability, and other device characteristics

6. a. Manufacturer's name
   b. Part number
   c. Manufacturing date code
   d. Pins
   e. Number one pin indicator
   f. Case

7. a. Dual in-line package—When viewed from above with the notch or indentation on the right, the number one pin is on the right above the notch or indentation
   b. Round case—When looking down on the pins, the first pin clockwise from the tab or aligned with the tab is the number one pin
   c. Square packages—The number one pin is marked with a dot or notched corner

8. (Answer should include any 5 of the following)

   a. ICs are more reliable due to fewer components to fail.
   b. ICs require less power.
   c. ICs generally cost less than the equivalent discrete components.

Answers to Written Test

d. ICs save space and weight.
e. ICs are easier to fabricate.
f. ICs usually make it easier to find compatible circuit components.

9. a. SSI
b. LSI
c. SSI
d. VLSI

10. a. Store ICs in ESD-protective containers.
b. Wear a grounded wrist strap when handling ICs.
c. Use properly grounded tools and equipment when connecting to ICs.
d. Use soldering equipment of the proper temperature range when soldering ICs.
e. Avoid overheating components during soldering.
f. Do not use acid solders or chloride or paste fluxes.
g. Do not install or remove ICs or PCBs with power applied.
h. Do not apply signals to inputs with power removed.
i. Consult data sheets for proper operational limits and conditions and connection requirements.
j. Use special test equipment to avoid shorting between terminals.
k. Do not use analog test equipment or continuity lights to check for shorts and opens.

11.

a.	D	e.	L	i.	D	m.	L
b.	L	f.	L	j.	D		
c.	L	g.	L	k.	L		
d.	D	h.	L	l.	L		

12.

a.	2	d.	4
b.	3	e.	1
c.	2	f.	4

13.

a.	7	d.	4	g.	3
b.	1	e.	5		
c.	2	f.	6		

14. a. Basic differential circuit
b. Single-input, single-output connection
c. Single-input, differential output
d. Differential input, differential output

15.

a.	2
b.	3
c.	4
d.	1

Answers to Written Test

16. a. Inverting input terminal
    b. Positive supply terminal
    c. Output terminal
    d. Third-stage common-collector amplifier
    e. Second-stage differential amplifier
    f. Negative supply terminal
    g. First-stage differential amplifier
    h. Noninverting input terminal

17.

a.	4	d.	8	g.	6
b.	2	e.	3	h.	5
c.	7	f.	1		

18. a. Inverting input terminal
    b. Noninverting input terminal
    c. Output terminal

19.

a.	5	d.	6
b.	1	e.	3
c.	4	f.	2

20.

a.	4	d.	7	g.	2
b.	1	e.	5	h.	8
c.	6	f.	3		

21.

a.	2	d.	6
b.	4	e.	5
c.	1	f.	3

22. a. The output is 180° out-of-phase with the input.
    b. The voltage gain of the op-amp stage is equal to the ratio between R_f to R_i.
    c. The input impedance is equal to the value of R_i.

23. a. Output is in-phase with the output.
    b. The output signal is equal to the difference between the input signal applied to the noninverting input and the feedback signal applied to the inverting input.
    c. The stage gain may be obtained through the equation

$$A_V = 1 + \frac{R_f}{R_i}$$

    d. The input impedance is very high, greater than the input impedance of the op-amp.

24. a. CD
    b. O
    c. CR

Answers to Written Test

25. a. Decreases
    b. Increases
    c. Increases
    d. Decreases
    e. Constant

26. a. D
    b. S
    c. D
    d. S
    e. S
    f. D

27. a. Hartley oscillator
    b. Colpitts oscillator
    c. Wein bridge oscillator

28. a. 2
    b. 1
    c. 3

29. a. Monostable
    b. Astable

30. a. Reference
    b. Input
    c. Propagation delay
    d. Changes
    e. Hysteresis
    f. Sometimes

31. a. 2
    b. 1
    c. 4
    d. 5
    e. 3

32. a. Amplifier
    b. Compared
    c. Error
    d. Input
    e. Frequency

33. b, c, d, e, g

Answers to Written Test

34. a. 4
b. 3
c. 1
d. 5
e. 2

35. a, d

36. a. C
b. S

37. a. Duration
b. Measure
c. Pulses
d. Either internal or external
e. Constant

38. a, b, c, d, e, f, g, h

39. a. Transmitters—Condition the signal and insert it into the transmission medium
b. Receivers—Detect the signal and convert it for use at the receiving station
c. Transceivers—Both transmit and receive signals

40. a. High
b. Oscillator
c. Modulation
d. Phase
e. Carrier
f. Amplitude
g. Frequency
h. High
i. Receiver
j. Superheterodyne
k. Amplifiers
l. FM
m. Detector
n. AGC, AFC
o. Output

41. a. Resonant
b. Fixed
c. Oscillator
d. Frequencies
e. Equal to
f. Image
g. Oscillator
h. Tuned

Answers to Written Test

42. a. Frequency modulation
b. Amplitude modulation
c. Phase modulation

43. a. Electromagnetic
b. Oscillator, oscillator
c. Frequencies
d. Waveguides

44. (Answer should include any 3 of the following)

a. UHF television broadcast
b. Satellite communications
c. Mobile radio communications
d. Cellular telephone communications
e. Telemetry
f. Radar systems
g. Microwave ovens

45. a. Light source—Generally a laser diode or LED that is part of a transmitter IC that includes circuitry for converting the source signal so that it can be amplitude modulated for transmission
b. Fiber optic cable—Glass or plastic core enclosed in optical cladding that refracts the light back into the core
c. Detector—Phototransistor or photodiode that is part of a receiver that converts the photo-sensitive device output signals back to its original format

46. a. Light
b. Information
c. Wide
d. Are not
e. Optical
f. Single-mode
g. Multimode
h. Attenuation
i. Multimode
j. Distances

47. a. Substance
b. May
c. Input
d. Measures
e. Stimulus
f. Either normally on or off
g. Modulating, generating
h. Either analog or digital
i. Operating
j. Measure

Answers to Written Test

48. (Answer should include any 5 of the following)

    a. Light
    b. Sound
    c. Humidity
    d. Temperature
    e. Flow
    f. Particles in a gas or liquid
    g. Radiation
    h. Chemicals
    i. Pressure, force, and torque
    j. Position
    k. Speed and acceleration rate
    l. Electrical characteristics

49.

49.	a.	2	d.	8	g.	7
	b.	5	e.	4	h.	1
	c.	3	f.	6		

50.

50.	a.	1	e.	11	i.	12	m.	8
	b.	4	f.	5	j.	3		
	c.	7	g.	13	k.	6		
	d.	9	h.	10	l.	2		

Linear Integrated Devices and Circuits
Unit 2

Written Test

Name ______________________________ Date ___________ Score ___________

1. Match terms associated with linear integrated devices and circuits to their correct definitions. Write the corresponding numbers on the blanks provided.

______a. Power consumed by a device during its operation so that this power is not available for the output signal

______b. Frequency at which an amplifier or filter begins rejecting signals or when a transistor amplification factor drops to 70.7 percent of its maximum value or 3 dB below maximum gain

______c. Operating condition of an amplifier in which the input signals are different in amplitude or duration

______d. Sensor device that requires an external power supply to provide electrical power for use in the sensor circuit

______e. Mathematical function performed by amplifier circuits in which the output is equal to the slope of the input waveform

______f. To mix signals, and in particular radio signals, together to produce a sum or difference signal

______g. Operating condition of an amplifier in which the input signals are identical in amplitude and duration

______h. Sensor device that converts inputs directly into electrical power for use in the sensor circuit

______i. Oscillator circuit that uses RC timing components to control the output signal frequency

1. Attenuation
2. Common mode
3. Common-mode rejection ratio
4. Crosstalk
5. Cutoff point
6. Deflection mode
7. Difference mode
8. Differentiation
9. Duty cycle
10. Generating sensor
11. Heterodyne
12. Integration
13. Inversion
14. Modulating sensor
15. Modulation
16. Multivibrator
17. Null mode
18. Offset null circuit
19. Phase-locked loop

Written Test

______j. Unwanted transfer of signals from one part of a device, circuit, or system to another part of the device, circuit, or system

______k. In a differential amplifier, the extent to which the circuit cancels unwanted signals, expressed as the ratio of the difference-mode gain to the common-mode gain

______l. Type of sensor circuit operation in which sensing takes place as a result of the sensor being acted upon and physically affected

______m. Process of combining signals so that one signal, called the carrier, maintains its basic waveform but follows a pattern driven by the second signal or modulating signal

______n. The percent or decimal fraction amount of time within a given time period that a device or circuit is on or in some other specified state such as high that is equivalent to on

______o. Oscillator that produces a nonsinusoidal waveform

______p. An oscillator-driven circuit that modifies its output signal to keep its output phase, frequency, or both synchronized with a reference signal

______q. Mathematical function performed by amplifier circuits in which the output is equal to the product of the area of the input waveform

______r. Op-amp circuit designed to compensate for input signal differences that result from imperfect matching of resistors, transistors, and other components

20. Power dissipation
21. Relaxation oscillator
22. Signal-to-noise ratio
23. Slew rate
24. Virtual ground

______s. Ungrounded point in a circuit that acts as a ground for all practical purposes in terms of signal processing

______t. Mathematical function performed by amplifier circuits in which the output is 180° out-of-phase from an AC input signal or of the opposite polarity of a DC signal

______u. Characteristic of an op-amp regarding how quickly the output can be changed between its upper and lower limits

______v. Type of sensor circuit operation in which sensing takes place as a result of the sensor resisting movement from a point of balance

______w. Reduction in or loss of signal strength, especially as a reduction in amplitude

______x. The ratio between the total signal (such as peak voltage) and that portion of the total signal that is unwanted; often expressed in decibels

2. Distinguish between active and passive components. Write an "A" beside the description of active components and a "P" beside the description of passive components.

______a. Circuit device that is basically static in its operation that generally requires no power for its characteristic operation

______b. Circuit device capable of a dynamic function, such as amplification, oscillation, signal control, and that usually requires a power supply for operation

Written Test

3. Match types of integrated circuit construction to their correct descriptions. Write the corresponding numbers on the blanks provided.

______a. Deposition of components on a substrate through use of a process such as silk-screening

______b. Use of thin layers of metals and oxides that form components on a single substrate of insulating material such as glass or ceramic

______c. Integration of circuits into a single piece of semiconductor material

______d. Integrated circuit consisting of a combination of two or more of the other methods

1. Hybrid
2. Monolithic
3. Thick-film
4. Thin-film

4. List ways of classifying IC packages.

a. ______________________________

b. ______________________________

c. ______________________________

5. Explain the meaning of the elements in an IC part number.

a. Prefix—______________________________

____

b. Part number—______________________________

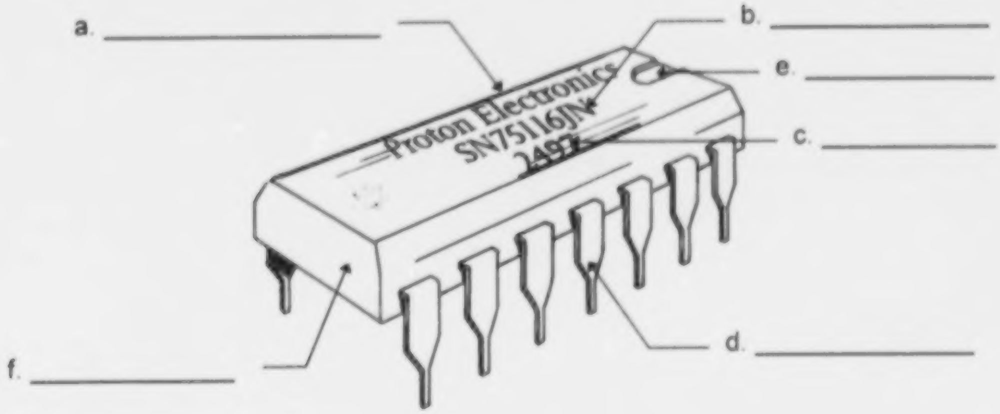
____

c. Suffix—______________________________

____

Written Test

6. Label the features of a dual in-line package integrated circuit.



7. Describe methods for identifying the number one pin on typical integrated circuit packages.

   a. Dual in-line packages—______________________________

   ____

   b. Round cases—______________________________

   ____

   c. Square packages—______________________________

   ____

8. List advantages of using integrated circuit devices as compared to equivalent circuits consisting of discrete components.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

Written Test

9. Classify ICs by the number of components they contain. For each IC described below, write "SSI" if the device represents small-scale integration, "LSI" if it represents large-scale integration, and "VLSI" if it represents very-large-scale integration.

_______a. An op-amp that contains 21 transistors, 12 resistors, and 2 capacitors

_______b. An IC used in a television receiver contains two IF amplifiers, an RF gain control amplifier, a second gain control amplifier, and a detector with more than 250 transistors embedded in it

_______c. An IC voltage regulator has 56 transistors, 48 resistors, 6 capacitors, 3 zener diodes, and 9 conventional diodes

_______d. One of the main ICs in a personal computer has more than 260,000 transistors

10. State guidelines for working with integrated circuits. For each key word or phrase given below, state the related guideline for working with integrated circuits.

a. Containers—____

____

b. Wrist straps—____

____

c. Grounded tools—____

____

d. Soldering temperatures—____

____

e. Components and heat—____

____

f. Solders and flux—____

____

g. Installing and removing ICs and PCBs—________________________________

____

h. Applying signals to inputs—______________________________

____

i. Data sheets—______________________________

____

j. Shorting between terminals—______________________________

____

k. Checking for shorts and opens—______________________________

____

11. Classify common integrated circuit devices as linear or digital. For each type of device listed below, write an "L" if the device is normally linear and a "D" if the device is normally digital.

______a. Microprocessors

______b. Switches and control circuits

______c. Timers

______d. Memory devices

______e. Filters

______f. Transmitters and receivers

______g. Sensors

______h. Amplifiers

______i. Logic devices

______j. Signal conversion circuits

______k. Counters

______l. Power supply and regulation devices

______m. Oscillators

Written Test

12. Classify amplifiers by their transfer functions. For each type of amplifier described below, indicate whether the amplifier is a

1) Current amplifier,
2) Voltage amplifier,
3) Transconductance amplifier, or
4) Transimpedance amplifier.

Write the number of the type of amplifier described in the blanks provided.

______a. A voltage-controlled integrated op-amp

______b. A voltage-controlled amplifier circuit constructed of discrete FETs

______c. A voltage-controlled IC that contains a direct-coupled multistage amplifier

______d. A current-controlled integrated op-amp

______e. A current-controlled, direct-coupled multistage amplifier constructed of discrete bipolar transistors

______f. A current-controlled IC that contains a direct-coupled multistage amplifier

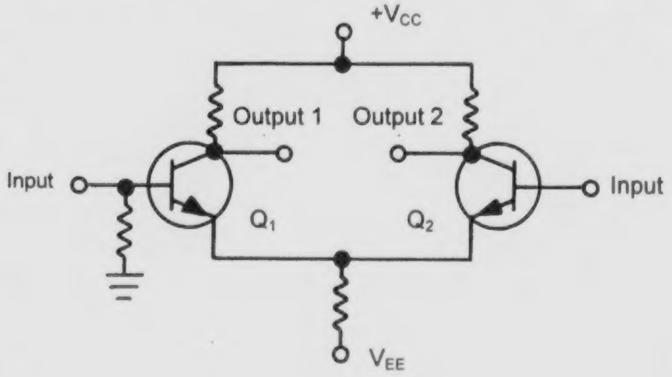
13. Match mathematical functions performed by amplifiers to their correct equations. Write the corresponding numbers on the blanks provided.

______a. $V_{out} = V_1 - V_2$	1. Addition
______b. $V_{out} = V_1 + V_2 + \ldots V_n$	2. Averaging
______c. $V_{out} = \dfrac{V_1 + V_2 + \ldots V_n}{n}$	3. Differentiation
	4. Integration
______d. $V_{out} = \dfrac{(V)\,(t)}{K}$	5. Inversion
______e. $V_{out} = -(V_{in})$	6. Noninversion
______f. $V_{out} = V_{in}$	7. Subtraction
______g. $V_{out} = K\dfrac{\Delta V}{\Delta t}$	

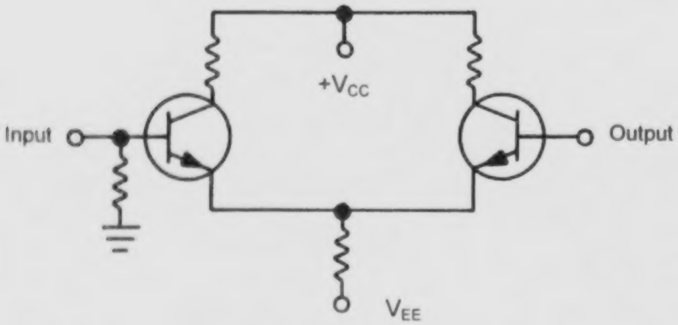
Written Test

14. Identify types of differential circuits.

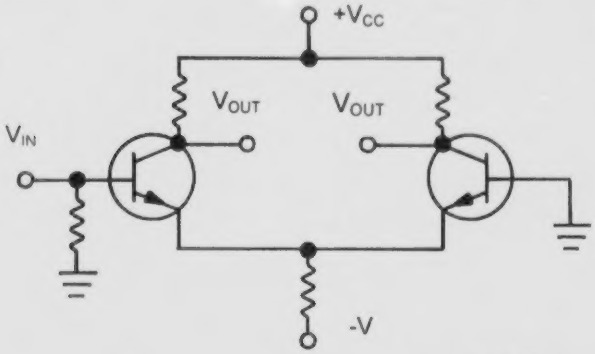
a. ______________________________


+V_{CC}
Output 1
Output 2
Input
Input
Q_1
Q_2
V_{EE}

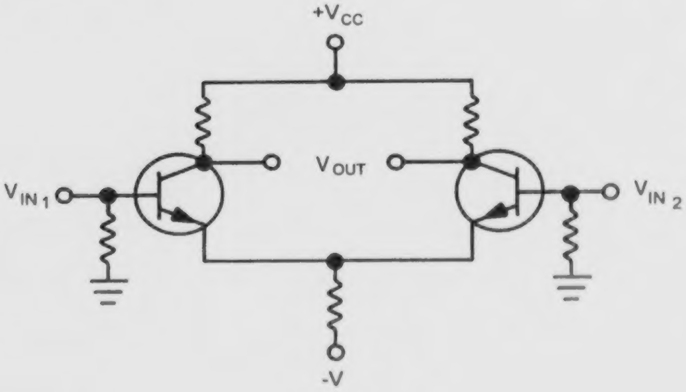
b. ______________________________


+V_{CC}
Input
Output
V_{EE}

c. ______________________________


+V_{CC}
V_{OUT}
V_{OUT}
V_{IN}
-V

d. ____



15. Match types of differential circuits to their correct descriptions. Write the corresponding numbers on the blanks provided.

_____a. Has two input terminals 180° out-of-phase with each other and two output terminals whose voltage is shown in the formula

$V_{out} = A(V_{in1} - V_{in2})$

_____b. Has one input terminal and two output terminals with one output in-phase with the input and the other 180° out-of-phase (though both outputs are of equal amplitude) and arranged so that the load can be connected to either or both outputs

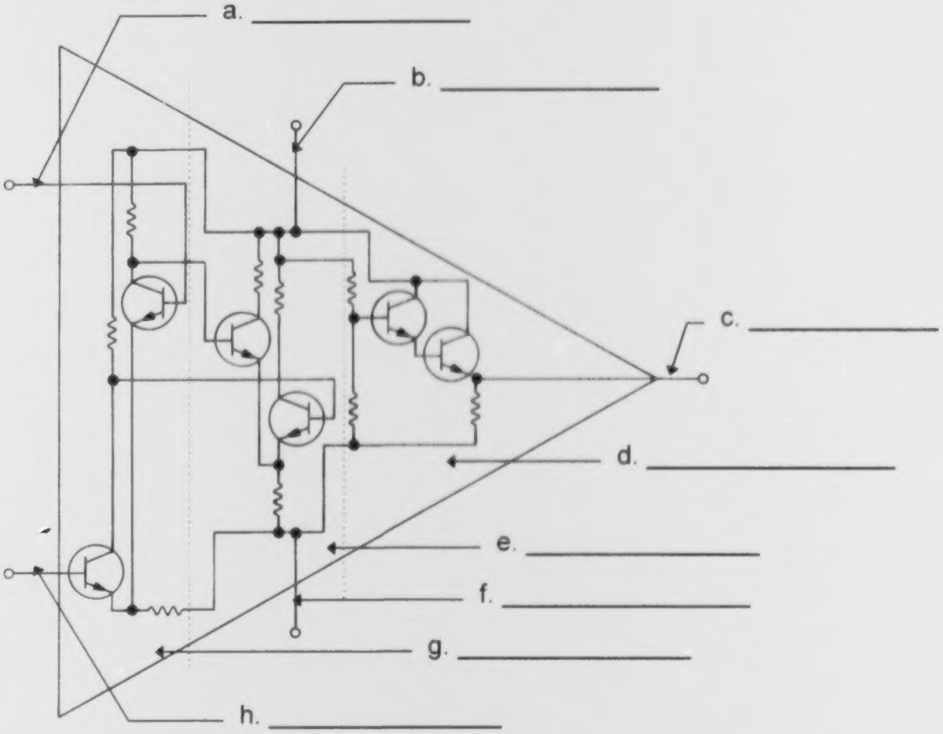
_____c. The output signal is in-phase with the input

_____d. Has two input terminals and two output terminals

1. Basic differential circuit
2. Differential input, differential output
3. Single-input, differential output
4. Single-input, single-output connection

Written Test

16. Label the components of an operational amplifier.



17. Match the components of an operational amplifier to their correct functions. Write the corresponding numbers on the blanks provided.

______a. Allows adjustment of circuit resistance to compensate for voltage differences that result from differences in circuit transistors and resistors

______b. Provides signal input for signals that will be 180° out-of-phase at the output

______c. Provide power to the circuit

______d. Ensures low output impedance

______e. Provides signal input for signals that will be in-phase at the output

______f. Amplifies input signal with high impedance and reduces signal noise

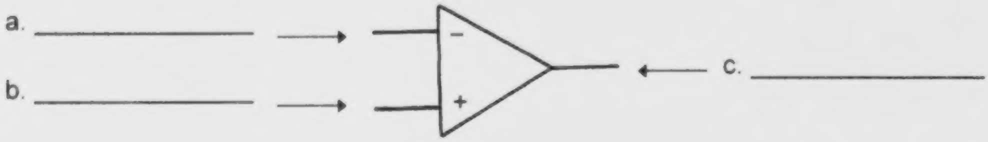
1. First-stage differential amplifier
2. Inverting input terminal
3. Noninverting input terminal
4. Offset null circuit
5. Output terminal
6. Second-stage differential amplifier
7. Supply terminals

______g. Uses the output of the first-stage amplifier to further reduce noise while ensuring good gain

______h. Provides modified signal to next circuit

8. Third-stage common-collector amplifier

18. Label the parts of the symbol for an operational amplifier.



19. Match the operational characteristics of an operational amplifier to their correct descriptions. Write the corresponding numbers on the blanks provided.

______a. Time that the output of the op-amp can be short-circuited to ground or to either supply voltage

______b. Maximum voltage that can be applied across the positive and negative inputs

______c. Ambient temperature range for which the op-amp will operate within the manufacturer's specifications

______d. Maximum positive and negative voltages that can be used to power the op-amp

______e. Maximum power that an op-amp is capable of dissipating in a specified ambient temperature

______f. Maximum input voltage that can be simultaneously applied between both inputs and ground

1. Differential input voltage
2. Input voltage
3. Internal power of dissipation
4. Operating temperature
5. Output short circuit duration
6. Supply voltage

Written Test

20. Match input-output parameters of an op-amp to their correct descriptions. Write the corresponding numbers on the blanks provided.

______a. Resistance at either input to the op-amp with the remaining input grounded

______b. Average of the currents flowing into both inputs

______c. Resistance seen looking inward from the op-amp output

______d. Maximum output current that the op-amp can deliver to a load

______e. Range of the voltage common to both inputs and ground

______f. Voltage that must be applied to one of the input terminals to give a zero output voltage

______g. Difference of the two input bias currents when the output is zero

______h. Maximum peak output voltage that the op-amp can supply without saturation or clipping

1. Input bias current
2. Input offset current
3. Input offset voltage
4. Input resistance
5. Input voltage range
6. Output resistance
7. Output short-circuit current
8. Output voltage swing

21. Match dynamic parameters of an op-amp to their correct descriptions. Write the corresponding numbers on the blanks provided.

______a. Measure of the ability of the op-amp to reject signals that are simultaneously present at both inputs; generally expressed in decibels

______b. Ratio of the output to input voltage of the op-amp without external feedback

______c. Amount of crosstalk between op-amps when more than one op-amp is present in a single package

______d. Maximum rate of change of output voltage under large-signal conditions

1. Channel separation
2. Common-mode rejection ratio
3. Large-signal voltage gain
4. Open-loop voltage gain
5. Rise time
6. Slew rate

______e. The 10-to-90-percent closed-loop, step-function response time of an amplifier under small signal conditions

______f. Ratio of the maximum voltage swing to the change in the input voltage required to drive the output from zero to a specified voltage

22. Describe the characteristics of an inverting amplifier. For each key word or phrase given below, describe how it applies to the characteristics of an inverting amplifier.

    a. Output phasing—____

    ____

    b. Voltage gain—____

    ____

    c. Input impedance—_______________________________________

    ____

23. Describe the characteristics of a non-inverting amplifier. For each key word or phrase given below, describe how it applies to the characteristics of a non-inverting amplifier.

    a. Output phasing—____

    ____

    b. Output signal value—____________________________________

    ____

    c. Stage gain—____

    ____

    d. Input impedance—_______________________________________

    ____

24. Distinguish between open-loop and closed-loop operation. Write an "O" beside the statement that describes open-loop operation, a "CR" beside the statement that describes closed-loop operation with regenerative feedback, and a "CD" beside the statement that describes closed-loop operation with degenerative feedback.

_______a. A portion of the output signal is directed back to the inverting input signal

_______b. No feedback is used

_______c. A portion of the output signal is directed back to the noninverting input terminal

25. Complete statements regarding the relationship among gain, bandwidth, and feedback in a closed-loop op-amp. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. Degenerative feedback (increases, decreases) gain.

b. Regenerative feedback (increases, decreases) gain.

c. Degenerative feedback (increases, decreases) the bandwidth.

d. Regenerative feedback (Increases, decreases) the bandwidth.

e. The gain-bandwidth product is _______________ for a given op-amp.

26. Distinguish between summing and difference amplifiers by their characteristics. Write a "D" beside each statement that describes difference amplifiers and an "S" beside each statement that describes summing amplifiers.

______a. The circuit has two inputs and one output.

______b. The circuit has two or more inputs with one output.

______c. The gain of the circuit is determined by the relationship of the resistor values.

______d. The common connection for the input resistors is known as the *summing point*.

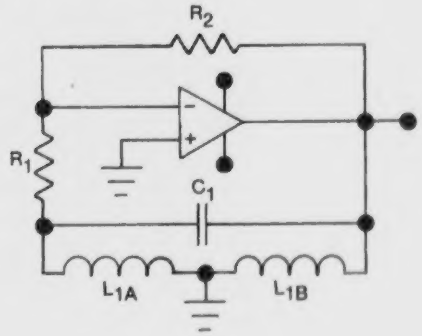
______e. All inputs feed into the negative terminal of the op-amp.

______f. One input feeds into the negative terminal of the op-amp and the other input feeds into the positive terminal of the op-amp.

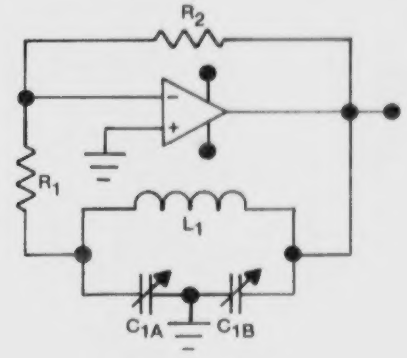
Written Test

27. Identify types of sinusoidal op-amp oscillators by their schematics.

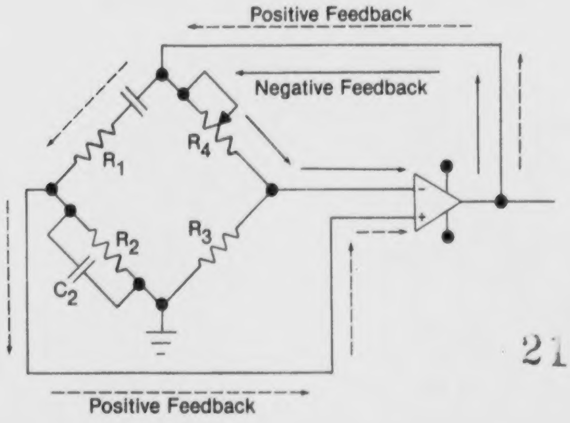
a. ______________________________


R2
R1
C1
L1A
L1B

b. ______________________________


R2
R1
L1
C1A
C1B

c. ______________________________


Positive Feedback
Negative Feedback
R1
R4
R2
C2
R3
Positive Feedback

Written Test

28. Match nonsinusoidal op-amp oscillators to their correct descriptions. Write the corresponding numbers on the blanks provided.

_____a. Operates like a monostable multivibrator, except that it has two stable states so that it can remain in either until a trigger signal is received or other conditions are met

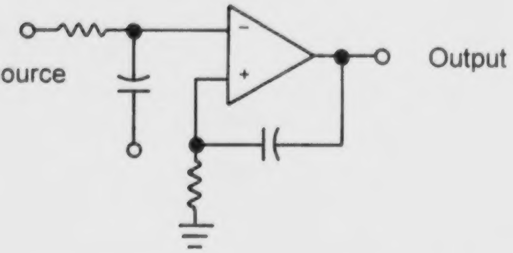
_____b. Produces a square-wave output, whose values are determined by the circuit components

_____c. Produces a constant output until a trigger signal is received, which drives the waveform to a second level where it remains until a specific duration of time has passed, whereupon it reverts back to the original level

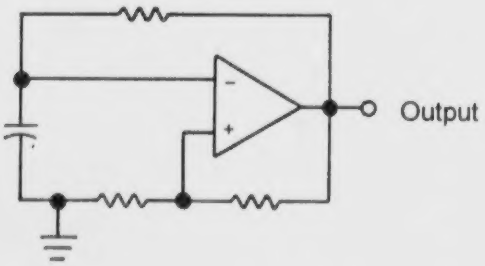
1. Astable multivibrator
2. Bistable multivibrator
3. Monostable multivibrator

29. Identify types of linear multivibrators by their schematics.

a. ______________________________



b. ______________________________



Written Test

30. Complete statements regarding the characteristics of comparators. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. Monitors a ______________ signal.

b. Changes output based on the value of the ______________ compared to the value of the reference signal.

c. The amount of time between the detection of a difference between the input signal and the reference signal until the output signal changes is referred to as ____________________.

d. The points at which the output signal ______________ are called *trip points* or *threshold points*.

e. The difference between the high and low trip points of a comparator is called ______________.

f. A comparator (always, sometimes, never) uses a feedback loop.

31. Match types of op-amp comparators to their correct operational descriptions. Write the corresponding numbers on the blanks provided.

______a. Uses positive feedback to the reference voltage to provide a narrow upper and lower threshold so that noise distortion will not cause undesired output changes

______b. Monitors a reference voltage and changes output once the input signal rises above the reference level

______c. Uses two op-amps so that each monitors either an upper or a lower threshold, with the output signals varying based on the input signal level

______d. Changes output each time the input signal waveform switches from positive to negative or from negative to positive

______e. Monitors a reference voltage and changes output when the input voltage varies from the reference voltage

1. Level sensing circuit
2. Schmitt trigger
3. Voltage comparator
4. Window comparator
5. Zero crossing detector

32. Complete statements about phase-locked loop operation. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

    a. Phase-locked loop (PLL) is a circuit consisting of a phase comparator, a voltage-controlled oscillator, and an _______________.

    b. The input signal is processed by the phase comparator and (added, compared) to the VCO signal.

    c. The phase comparator outputs an _______________ signal if there is a frequency difference between the two signals.

    d. The VCO shifts frequencies until it matches the (input, output) signal.

    e. Once the signals match, the VCO locks onto the input signal (amplitude,frequency) and changes with it as long as it is within an acceptable range.

33. Select from a list correct statements about the characteristics of active filters. Write an "X" beside each statement below that is a correct statement about the characteristics of active filters.

    ______a. Active filters consist of resistors, capacitors, and inductors.

    ______b. In a band-pass active filter, two RC branches or two op-amps are used to filter frequencies above and below a given bandwidth.

    ______c. The adjustment capability is provided through the use of an op-amp and an RC feedback circuit.

    ______d. In a high-pass active filter, high frequencies are routed through the RC branch, while low frequencies are shunted to ground.

    ______e. In a notch active filter, the frequencies within a given range around a center frequency are filtered and signals outside that range pass through.

    ______f. Active filters must be changed or cleaned periodically as they become clogged.

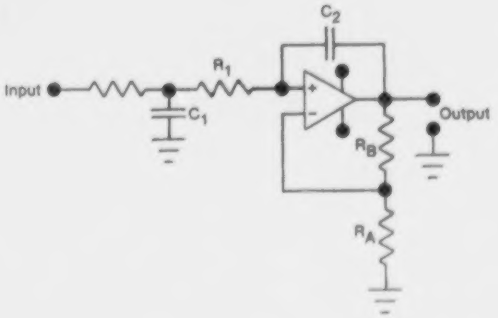
    ______g. Active filters perform functions similar to passive filters but have the added capability of adjusting for various frequencies.

    ______h. In a low-pass active filter, high frequencies are routed through the RC branch, while low frequencies are shunted to ground.

Written Test

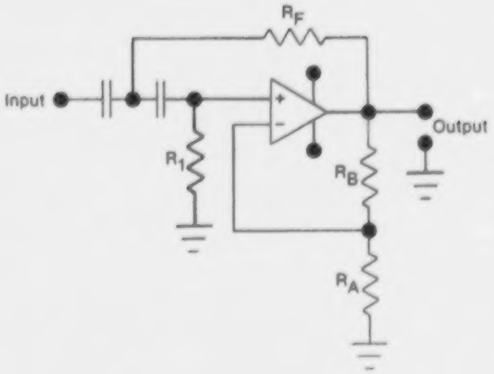
34. Match active filter circuits to their correct schematics. Write the corresponding numbers on the blanks provided.

_______a.

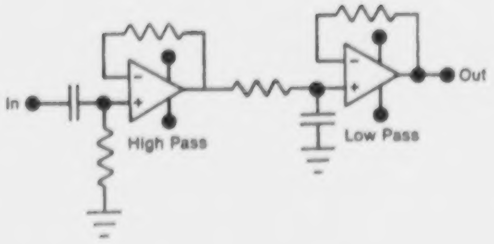

C2
R1
Input
C1
Output
RB
RA

1. Band-pass active filter with dual op-amp branches
2. Band-pass active filter with dual RC branches
3. High-pass active filter
4. Low-pass active filter
5. Notch active filter

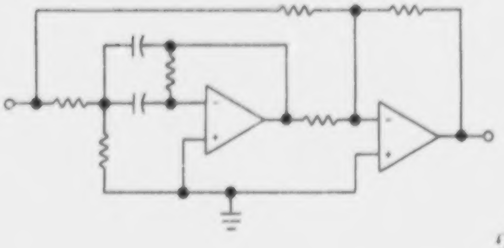
_______b.


RF
Input
R1
Output
RB
RA

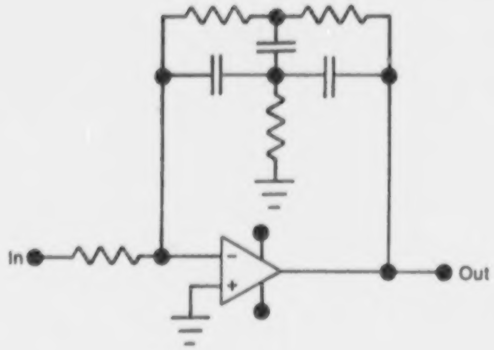
_______c.


In
High Pass
Low Pass
Out

_______d.



______e.



35. Select from a list correct statements about transimpedance amplifiers. Write an "X" beside each item listed below that is a correct statement about transimpedance amplifiers.

______a. Voltage controlled

______b. Consists of two stages like an op-amp

______c. Has a fixed gain-bandwidth product

______d. Very fast slew rate

______e. Current controlled

36. Distinguish between IC switches and control devices by their descriptions. Write an "S" beside the item below that describes a switch and a "C" beside the item that describes a control.

______a. Adjusts circuit flow over a defined range

______b. Opens or closes circuit

37. Complete statements regarding IC timers. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. A timer may be used to control the start and ________________ of an operation.

b. A timer may be used to ________________ the duration of an operation.

c. Electronic timers use oscillators to trigger ________________ to indicate the passing of time.

d. The oscillator is (internal, external, either internal or external) to the timer.

e. The oscillator may be driven by a crystal, (constant, variable) frequency signal, or other generator capable of producing a regularly recurring signal.

Written Test

38. Select from a list correct statements regarding IC counters. Write an "X" beside each item listed below that is a correct statement regarding IC counters.

______a. Counters register the number of occurrences of an event.

______b. A counter may recognize the event by the receipt of a signal.

______c. A counter may recognize the event by the failure to receive a signal.

______d. A counter may be continuously cumulative, counting occurrences as long as it is operational.

______e. A counter may be manually resettable.

______f. A counter may be self-resetting.

______g. A counter may monitor continuously.

______h. A counter may monitor on a sampling basis, with samples taken at prescribed or random intervals or samples taken from larger collections of the substance or energy to be counted.

39. Describe the function of IC transmitter and receiver devices. For each key word or phrase given below, describe how it applies to the function of IC transmitter and receiver devices.

a. Transmitters—____

____

b. Receivers—____

____

c. Transceivers--____

____

40. Complete statements regarding the operation and principles of an RF circuit. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. Energy can be transmitted from one place to another through the use of (high, low) frequency waves called *radio waves* or *radio frequencies* (RF).

b. The transmission begins as alternating current that is used to power an (amplifier, oscillator), whose output is routed to an antenna that converts the oscillations into radio waves.

Written Test

c. The radio waves can be made to represent information through a process called _______________ in which the signal containing the information (such as an audio or video signal) is combined with the oscillator signal to produce a modulated signal.

d. The signal's amplitude, frequency, or (phase, intermediate frequency) can be modulated.

e. The RF signal is called the _______________.

f. With (amplitude, frequency) modulation, the bandwidth of the signal is one amplitude above and below the carrier frequency with these upper and lower frequencies being called *sidebands*.

g. With (amplitude, frequency) modulation, the carrier is called the *center frequency*, which modulates to a higher frequency when a positive amplitude is applied by the information signal and to a lower frequency when a negative amplitude is applied.

h. When the radio waves strike a receiving antenna, a (high, low) frequency current is induced in the antenna that duplicates the broadcast signal.

i. The receiving antenna is connected to a tuned radio-frequency _______________ that is set to detect signals within a given bandwidth and amplify the RF signals.

j. The RF signals are fed through a _______________ receiver, which contains an oscillator that generates an intermediate frequency and mixes it with the amplified RF signal.

k. The combined signal is routed through one or more IF (oscillators, amplifiers) that filter the signal.

l. In (AM, FM) reception, the signal then passes through a limiter to remove amplitude variations that would distort the output signal.

m. Next the signal passes through a _______________ that separates the information portion of the signal and sends it to the output amplifier.

n. In some systems, the detector may also feed signals to an automatic gain control for AM systems or automatic frequency control for FM systems that is fed back to the amplifiers for (AFC, AGC) or oscillator for (AFC, AGC) to maintain a more constant output volume.

o. The (input, output) amplifier—typically an audio amplifier for radio broadcasts—strengthens the signal and routes it to the output devices, such as speakers.

Written Test

41. Complete statements regarding the operation and principles of an IF circuit. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. The RF amplifiers and detector of a receiver circuit must be _______________ with each other and provide an adequate bandwidth coverage in order to have good reception across the full range of broadcast frequencies.

b. These problems can be reduced by tuning the radio to a few (fixed, variable) frequencies, which is not possible if a radio is to be capable of receiving any broadcast station.

c. A superheterodyne receiver overcomes these problems by using an (oscillator, amplifier) to insert a signal of a fixed frequency that is added to the received signal in a mixer.

d. The mixer outputs signals at four different (amplitudes, frequencies): the received signal, the signal from the oscillator, a summed signal of the received signal and the oscillator signal, and a difference signal of the received signal minus the oscillator signal.

e. The difference signal will be (greater than, equal to, less than) the IF value and will pass through the filters of the IF amplifiers to the detector.

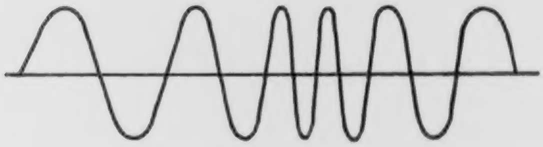
f. It would be possible for another signal to pass through the receiver if the antenna picked up a signal on a frequency equal to the sum of the IF and the oscillator frequency in a kind of noise referred to as _______________ *interference.*

g. To eliminate this interference, many IF circuits insert two signals that can mix with the (amplifier, oscillator) signal to produce the IF, with the first signal being the tuned frequency and the second being called the image frequency.

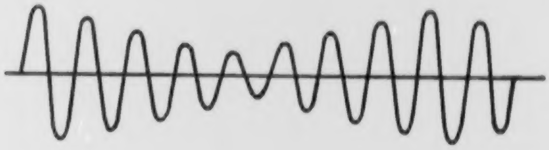
h. The IF circuit rejects the image frequency because it is outside the resonance of the (tuned, image) frequency.

42. Identify types of signal modulation by their waveforms.

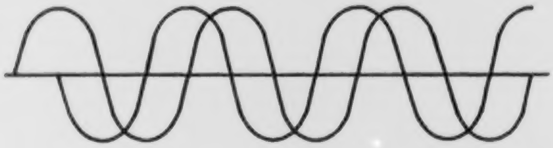
a. ______________________________



b. ______________________________



c. ______________________________



43. Complete statements about the characteristics of microwaves. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. Microwaves are the part of the ______________ spectrum between 1 and 300 gigaHertz (GHz).

b. Microwaves are usually generated by an electron-tube UHF (amplifier, oscillator) called a *klystron* or by another type of electron-tube (amplifier, oscillator) called a *magnetron*.

c. Some ICs are specifically designed to operate at microwave (amplitudes, frequencies) and are referred to as *microwave integrated circuits*.

d. Microwaves are normally transmitted through the air or through coaxial cable or specially constructed chambers called ______________.

Written Test

44. List uses of microwave circuits in electronic systems.

a. ______________________________

b. ______________________________

c. ______________________________

45. Describe the parts of a fiber optic circuit. For each key word or phrase given below, describe how it applies to the parts of a fiber optic circuit.

a. Light source—______________________________

____

b. Fiber optic cable—______________________________

____

c. Detector—______________________________

____

46. Complete statements about fiber optic circuits. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. Use of ______________ provides a very fast carrier.

b. The amount of ______________ that can be transmitted in a given period of time is called *data rate* and is measured in *bauds* (bits per second).

c. The speed of light allows transmission of a very (wide, narrow) bandwidth, resulting in a high data rate.

d. Fiber-optics (are, are not) affected by electromagnetic interference.

e. (Electromagnetic, Optical) interference can be eliminated by an opaque covering of the fiber.

f. Transmission down the center of the cable is called (single-mode, multimode) propagation.

g. Transmission that relies on light being reflected off the cladding is called (single-mode, multimode) propagation.

h. Loss of signal from light being absorbed by the cladding is called ______________.

Written Test

i. As the light travels through the cable in (single-mode, multimode) propagation, the individual beams of light can travel different distances due to being refracted at varying numbers of times, leading to distortion of the signal as the pulses spread.

j. Both attenuation and pulse spreading limit the (bandwidths, distances) over which signals can be transmitted without serious distortion for a given data rate.

47 Complete statements about the operation of IC sensor devices. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. A sensor circuit normally consists of a *sensor* to detect or measure a _______________ or energy and an *actuator* to initiate a response to the detection or measurement.

b. A sensor circuit (may, must) also contain *signal conditioning devices* to make the sensor output more usable.

c. A sensor circuit monitors an environment to which its (input, output) interface is exposed.

d. The sensor monitors for the presence or absence of a substance or energy or _______________ the quantity of a substance or energy.

e. The substance or energy that causes a response in the sensor is called a _______________.

f. A sensor circuit can be (normally on, normally off, either normally on or normally off).

g. In terms of its power output, a sensor may be (generating, modulating), meaning that it uses an auxiliary power source, or (generating, modulating), meaning that it converts the input signal directly to power output.

h. The output signal is (analog, digital, either analog or digital).

i. The _______________ mode of a sensor may be defined as *deflection mode*, where the sensor is at rest and the presence or absence of the stimulus causes a change (physical, chemical, electrical, etc.) in the sensor, or as *null mode*, in which the sensor generates a force to oppose the stimulus to try to maintain a steady state.

j. Sensors may also be classed according to what they sense or _______________.

Written Test

48. List types of IC sensor stimuli. List at least five substances, forces, energies, or conditions that sensors are used to detect or measure.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

49. Match types of photo-sensitive devices to their correct uses in linear circuits. Write the corresponding numbers on the blanks provided.

______a. Device that functions as both a photoelectric cell and a switch

______b. Device that counts objects as a result of their breaking a beam of light

______c. Device that conducts in one direction and whose conductivity varies in accordance with the amount of light that falls upon it

______d. Device that converts light into electricity specifically as a power source

______e. Device that converts light into electricity

______f. Device whose electrical resistance varies as a function of the amount of light applied to the device

______g. Device that generates electrical current when exposed to light and then processes that signal for amplification, oscillation, or switching

______h. Device that acts as both a photosensor and a switch so that currents can be switched on by means of a light signal

1. Light-activated SCR
2. Light-activated SCS
3. Photodiode
4. Photoelectric cell
5. Photoelectric counter
6. Photoresistor
7. Phototransistor
8. Photovoltaic cell

Written Test

50. Match types of IC signal processing functions to their correct descriptions. Write the corresponding numbers on the blanks provided.

______a. The distance that the signal fluctuates above and below a prescribed value (usually 0) is increased or decreased

______b. The method of presenting the signal values in a numerical representation changes from one system to another

______c. The rate at which a fluctuating signal's timing is increased or decreased

______d. A given point in the waveform of the output signal, such as its peak, is shifted from the corresponding point of the input signal

______e. The percent of signal voltage that is usable compared to that that is not usable is changed (usually reduced)

______f. The signal is changed from one that varies between discrete values to one that varies in a continuous fashion or from one that varies in a continuous fashion to one that varies between discrete values

______g. The general form of the output signal is different from that of the input signal

______h. The wattage of the output signal is different than that of the input signal

______i. The voltage of the output signal is different than that of the input signal

______j. The amperage of the output signal is different than that of the input signal

______k. The signal is rectified or oscillated

______l. The output signal compares to the input signal in a way that can be mathematically defined

______m. The output signal compares to the input signal in a way that can be described by a logic statement

1. Amplitude
2. Arithmetic functions
3. Current gain
4. Digital coding
5. Digital versus analog
6. Direct versus alternating current
7. Frequency
8. Logic combinations
9. Phasing
10. Power gain
11. Signal-to-noise ratio
12. Voltage gain
13. Waveform shape

*Permission to duplicate this test is granted.

Linear Integrated Devices and Circuits
Unit 2

Unit Evaluation Form

Student Name ______________________________ Unit Rating ______________

Assignment Sheet Ratings

Assignment Sheet 1—Calculate the Closed-Loop Gain for an Inverting and a Noninverting Amplifier Rating _____

Comments: ____

____

Assignment Sheet 2—Calculate the Output Voltage of a DC Summing Amplifier Rating _____

Comments: ____

____

Assignment Sheet 3—Determine Specifications for Commercially Available Op-Amps Rating _____

Comments: ____

____

Job Sheet Ratings

Job Sheet 1—Construct and Test an Inverting Amplifier Rating _____

Comments: ____

____

Job Sheet 2—Construct and Test a Noninverting Amplifier Rating _____

Comments: ____

____

Job Sheet 3—Construct and Test a Differential Amplifier Rating _____

Comments: ____

____

Unit Evaluation Form

Job Sheet 4—Construct and Test a DC Summing Amplifier Rating _____

Comments: ____

____

Job Sheet 5—Construct and Test a Hartley Oscillator Using an Op-amp Rating _____

Comments ____

____

Job Sheet 6—Construct and Test a Low-Pass Active Filter Rating _____

Comments: ____

____

Job Sheet 7—Construct and Test a Timer Circuit Rating _____

Comments: ____

____

Job Sheet 8—Troubleshoot Linear Circuits Rating _____

Comments : ____

____

Written-Test Scores

Pretest _______ Posttest _______ Other _______

Other ____

____

Teacher Signature ______________________________ Date ______________

Student Signature ______________________________ Date ______________

*Permission to duplicate this form is granted.

227

Linear Integrated Devices and Circuits
Unit 2

Supplement 1—Report on an Integrated Circuit

Introduction The progress that is being made in the development and manufacture of IC devices has been incredible over the past few years, and indications are that this will continue for many years to come. Along with these advances come changes in operation, performance capabilities, handling requirements, fabrication and test procedures, and other characteristics that affect how an electronics technician works with such devices. Therefore, technicians must remain current on developments in the component industry and be able to obtain technical data on new components that they encounter, including devices that may be new to them as they start their careers. This supplement will provide students an opportunity to research information on an integrated circuit.

Directions Copy the form on the second page following for distribution to the students. Use the information in the introduction to this supplement or similar thoughts to motivate the class on the need to stay current on developments in component technology. Assign each student an appropriate component or allow the students to choose components. Provide the necessary data resources for the students to use in doing their research. Have the students turn in written reports—either the completed forms or more formal reports to your format—or give oral reports to the class so that all students get exposed to the research done by others.

Note: This supplement lends itself for flexible use in the classroom. Consider the following applications and alternatives:

- Use the supplement only for students who are ahead of the rest of the class to expand their studies.
- Use ICs that relate to the objectives of this unit. Have some students do amplifiers, some oscillators, some filters, some RF circuits, some microwave ICs, etc. Have the students share their reports as the class is studying that particular IC. This not only makes the exercise more relevant but also keeps the reports from being bunched up in a few class periods.
- Tailor the complexity of the component to the student's abilities. Have advanced students report on more complex or specialized components, while other students report on the more common applications. For example, one student may report on a simple op-amp, while another may report on a highly complex receiver-tuner IC.
- Use variations in the report format, allowing the students some opportunities for creativity. These variations should be appropriate for the abilities and interests of your students. For example, you may have

the students create posters about their assigned components. If you have a computer network available, you can create an "internet" with the students creating "home pages" that other students can access. You can compile a component catalog using the reports. The catalog may be a book, a computer file, or a videotape of oral reports or posters.

- Have students use the assigned component in a circuit application. For example, assign components that are used in the job sheets and have the students complete their reports before doing the job sheet. Develop additional projects using the assigned components.
- Customize the report form by adding questions that apply specifically to the assigned component, similar to the types of questions that accompany the discussion step of many job sheets.

Supplement 1

Report on an Integrated Circuit

Student Name ______________________________ Date ______________

Name/Number of Component ______________________________

Manufacturer ______________________________

General uses of component ______________________________

____

Available packages (materials and types) ______________________________

____

Key Characteristics

Note: Characteristics presented in data sheets will vary greatly among components and manufacturers. List the key characteristics provided for each category given below and state what the characteristic is. For example, for voltage, if the data sheet lists nominal operating voltage, maximum forward voltage, and maximum reverse voltage, list those characteristics and state the values given.

Voltage (such as repetitive reverse voltage, zener voltage, forward voltage, breakdown voltage, etc.)

Current (such as average rectified forward current, peak surge current, maximum forward current, etc.)

Power dissipation

Operating and Storage Temperatures

Soldering Temperature, Time, and Solder Flux Specifications

On the back of this sheet, list other characteristics (impedances, capacitances, etc.) or provide sketches of leads, characteristic curves, electrical equivalents, or other data that may be useful.

***Permission to duplicate this form is granted.**

Linear Integrated Devices and Circuits
Unit 2

Supplement 2—Report on a Sensor Device

Introduction Your students are probably unaware of how frequently they encounter sensors and actuators. This supplement will help improve their awareness while also expanding their exposure to some critical types of sensors that they are likely to encounter as electronic technicians. However, the supplement is also easily customized to meet the needs of your class. For example, they can simply report on sensor devices if your studies tend to deal with top-level objectives or if sensors are not an area of emphasis in your program. Or you can get deeper into the subject by looking at sensor-actuator circuits. You can go even farther by having the students look at specific applications of such circuits. This is especially practical if your facility offers training in aviation technology, refrigeration, hydraulics, and similar programs with complex control systems or if you have industry support available that will allow your students access to such systems in nearby facilities.

Below is a list of some sensor circuits to consider when making this assignment. If your program does not include this degree of emphasis on sensors, you might consider at least discussing these circuits with the students so that they will have a bit broader understanding of common sensors.

- Strain gauges
- Resistive temperature detectors
- Thermistors
- Magnetoresistors
- Light-dependent resistors
- Hygrometers
- Instrumentation amplifiers
- Hall-effect devices
- Thermocouples
- Magnetoelastic sensors

Directions Copy the form on the next page for distribution to the students. Use the information in the introduction to this supplement or similar thoughts to motivate the class on the need to stay current on developments in component technology. Assign each student an appropriate component or allow the students to choose components. Provide the necessary data resources for the students to use in doing their research. Have the students turn in written reports—either the completed forms or more formal reports to your format—or give oral reports to the class so that all students get exposed to the research done by others.

Note: Supplement 1 contains a number of suggestions on how to present this supplement and customize it for use in your classroom.

Supplement 2

Report on a Sensor Device

Student Name ______________________________ Date ________________

Name/Number of Component ____

Manufacturer ____

General uses of component ______________________________________

____

Available packages (materials and types) ___________________________

____

Key Characteristics

Note: List key characteristics that affect the operation of this device and circuits in which it is used. Such characteristics may be presented in data sheets, available in equipment operating manuals, or in other data sources.

____

____

Principle applications ____

____

Signal conditioning requirements ____________________________________

____

Actuator devices ____

____

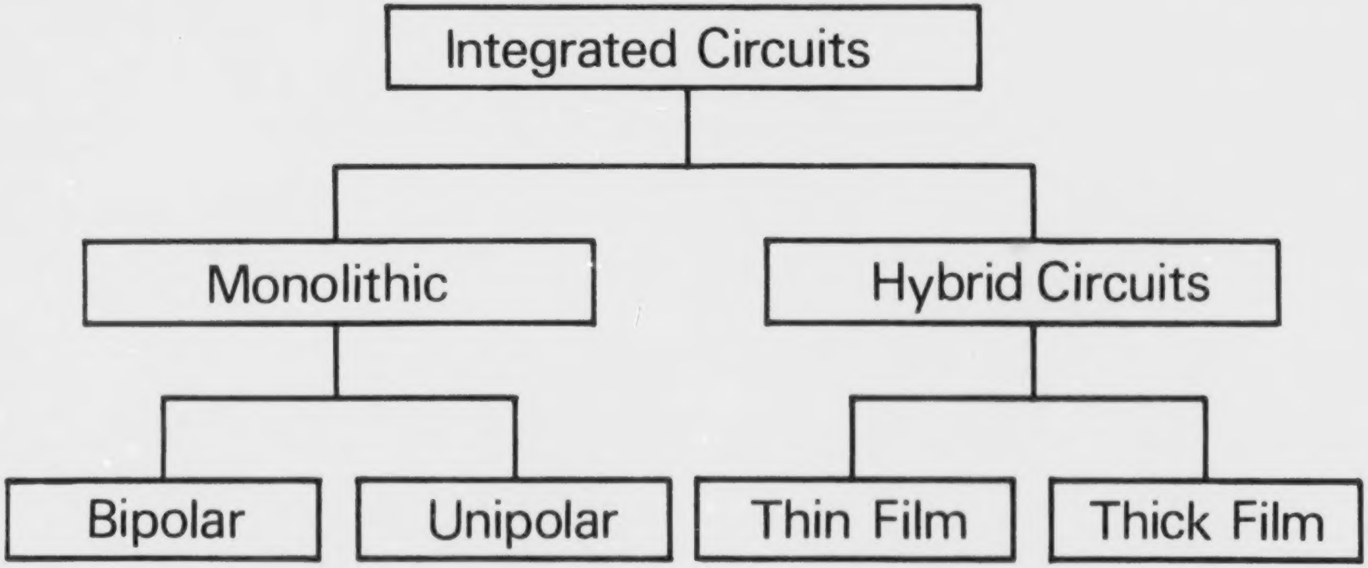
Basic operating principles ____

____

On the back of this sheet, list other characteristics or provide sketches of leads, characteristic curves, electrical equivalents, or other data that may be useful.

***Permission to duplicate this form is granted.**

Categories of Integrated Circuits



Integrated Circuits

Monolithic

Hybrid Circuits

Bipolar

Unipolar

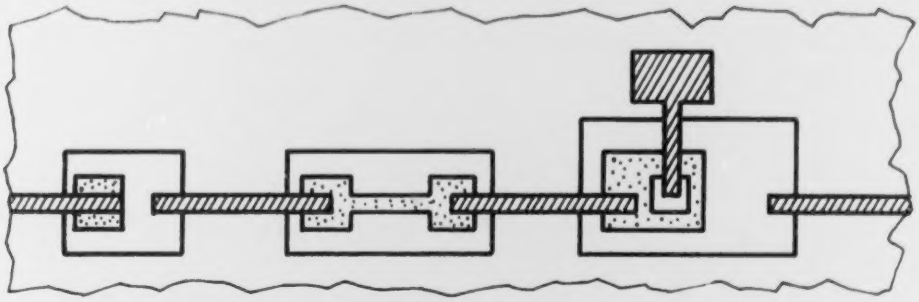
Thin Film

Thick Film

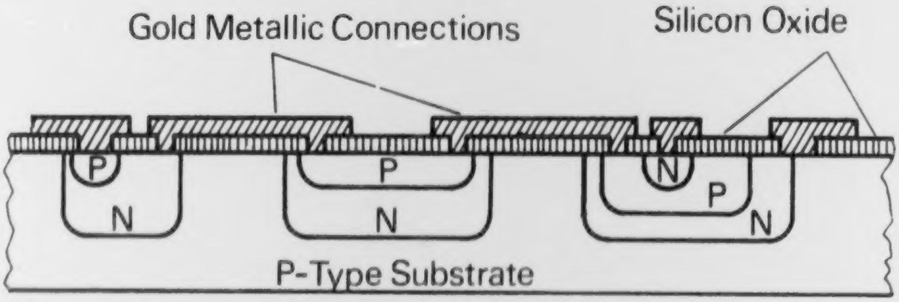
General Electronics Technician. Semiconductor Devices and Circuits, Unit 2
Teacher Page 57

TM 1

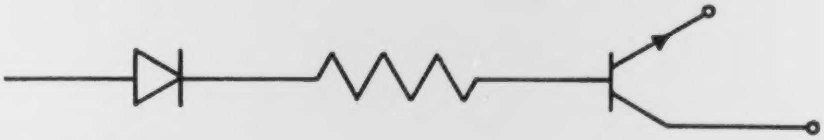
Monolithic Integrated Circuits



Top View (oxide omitted)

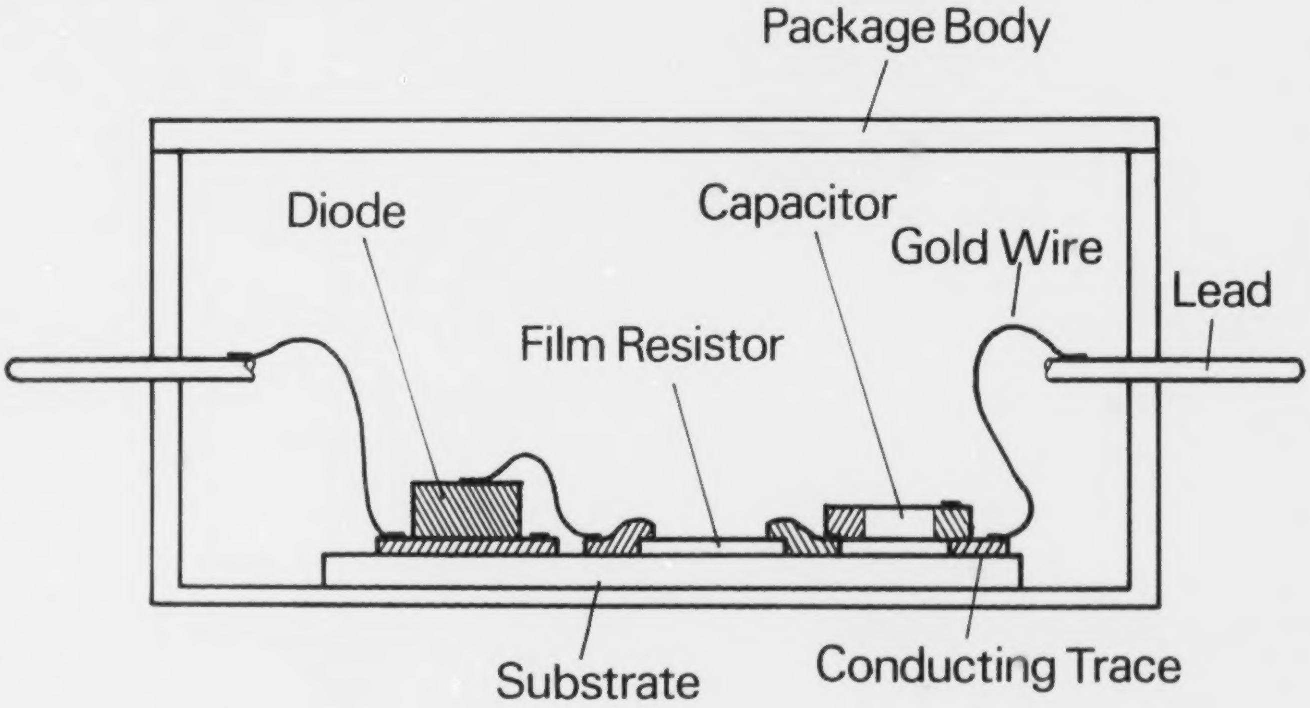

Gold Metallic Connections
Silicon Oxide
P
N
P
N
N
P
N
P-Type Substrate

Cross Section



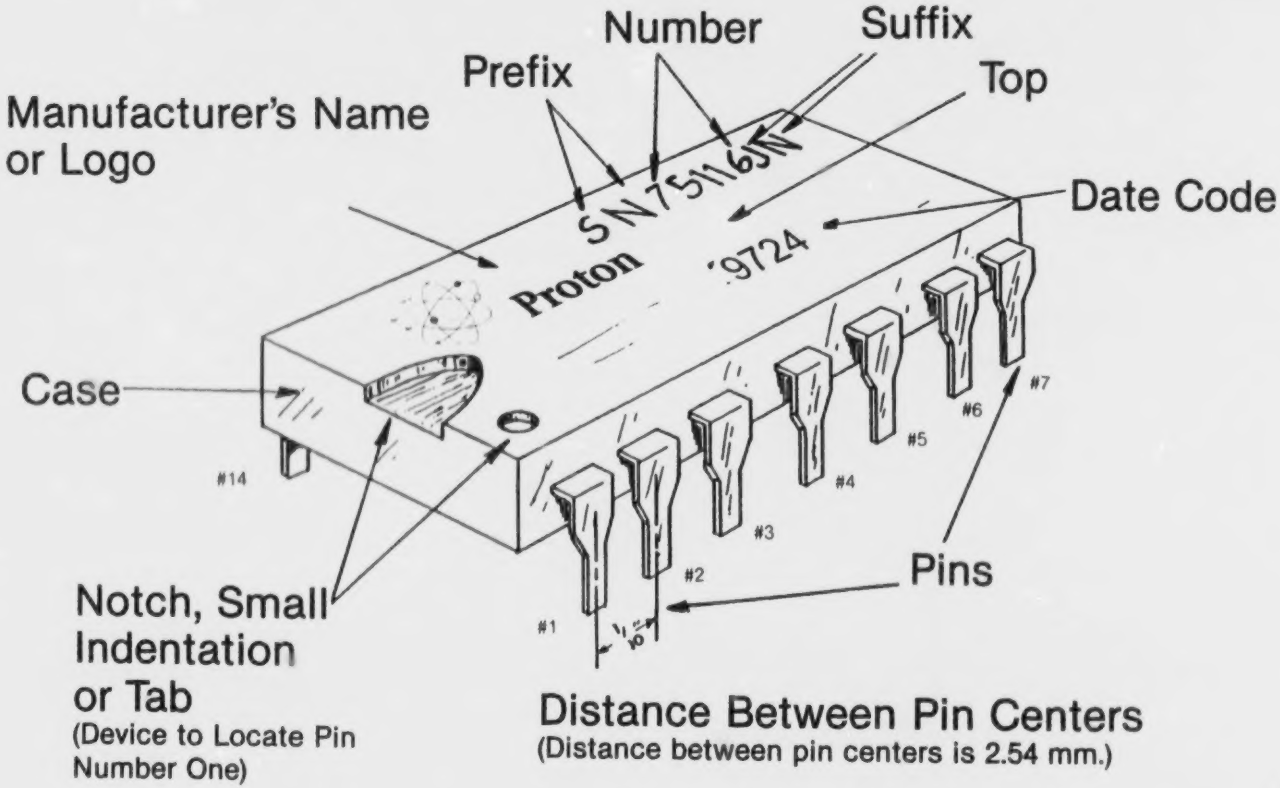
Schematic

Hybrid Thick-Film Circuit

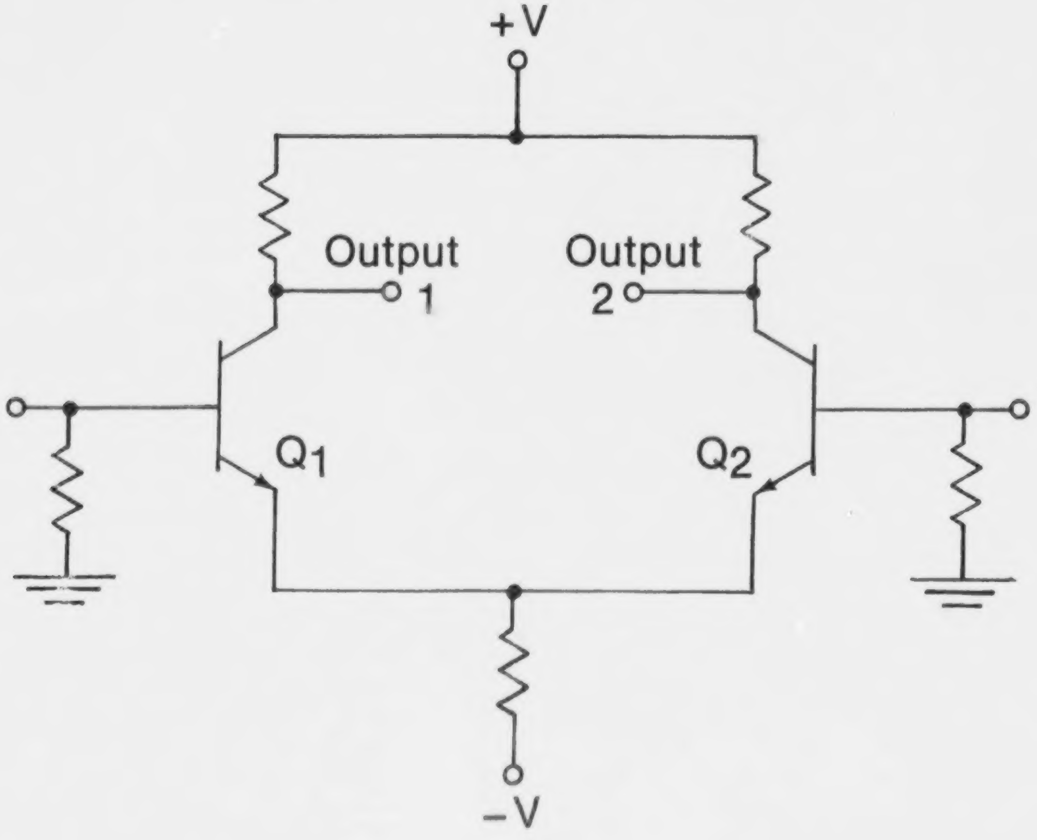

Package Body
Diode
Capacitor
Gold Wire
Lead
Film Resistor
Substrate
Conducting Trace

TM 3

Features of a Typical Dual In-Line Package Integrated Circuit

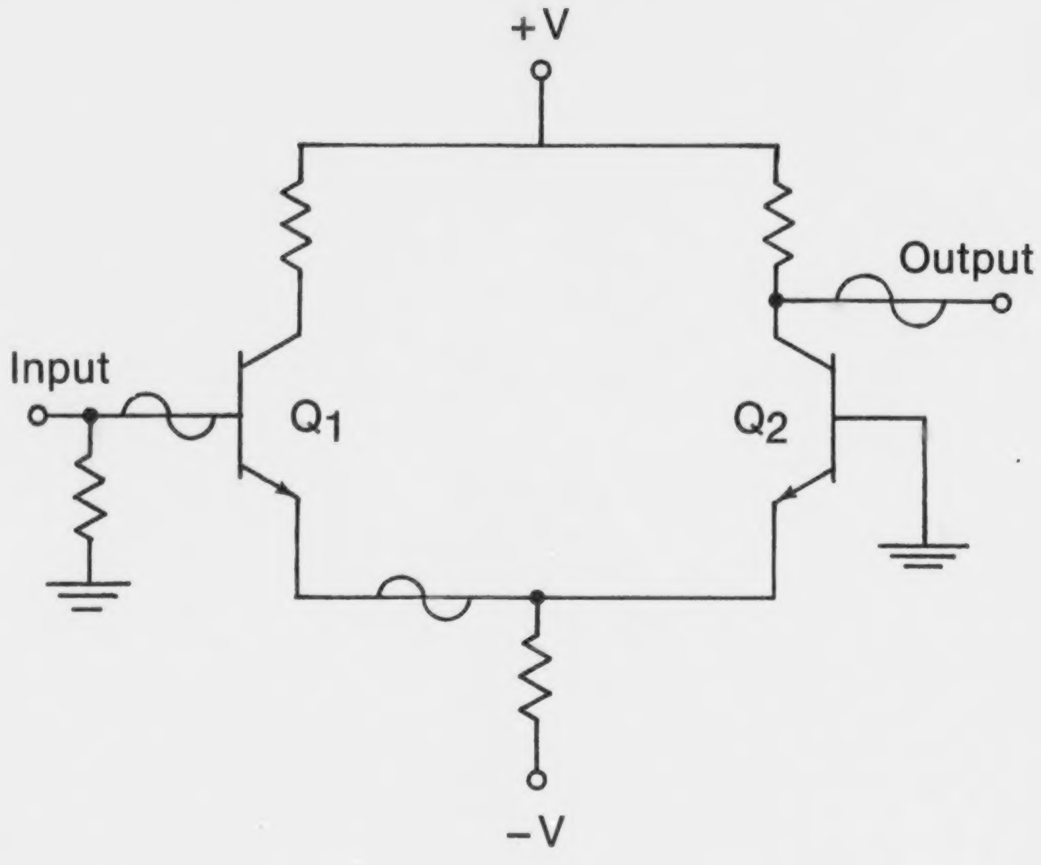

Manufacturer's Name or Logo
Prefix
Number
Suffix
Top
Date Code
Case
SN75116JN
Proton
'9724
#14
#1
#2
#3
#4
#5
#6
#7
1/10"
Pins
Notch, Small Indentation or Tab
(Device to Locate Pin Number One)
Distance Between Pin Centers
(Distance between pin centers is 2.54 mm.)

Basic Differential Amplifier

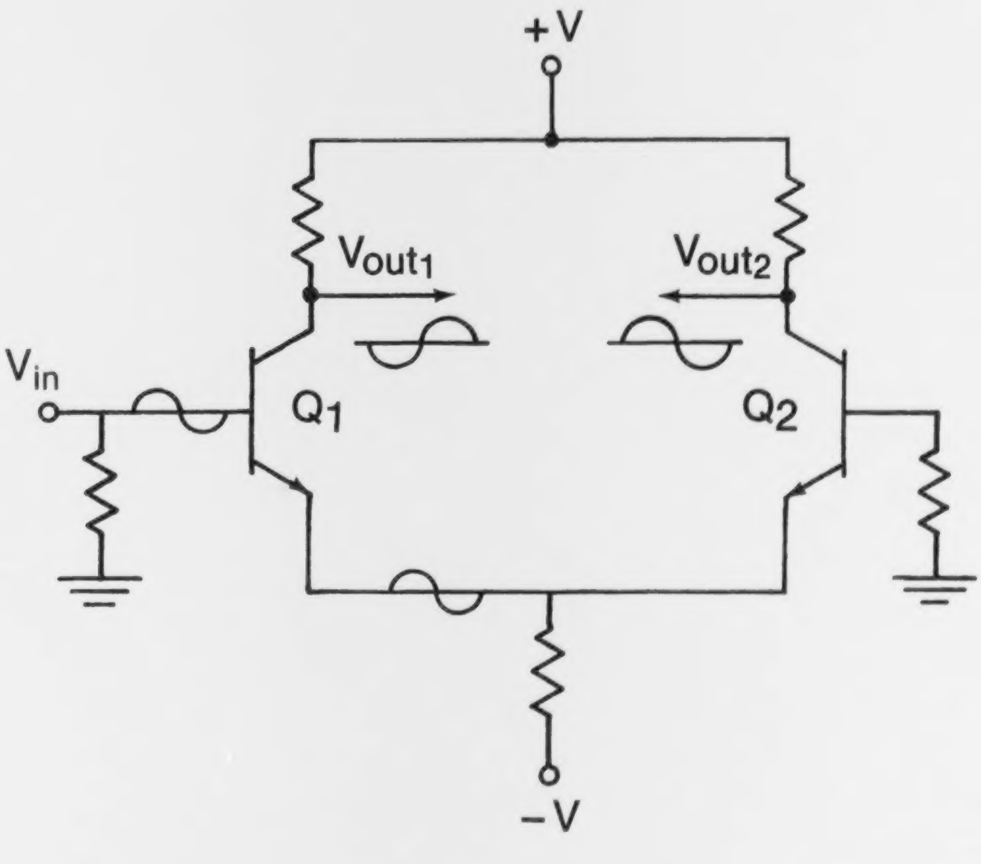

+V
Output 1
Output 2
Q1
Q2
−V

TM 5

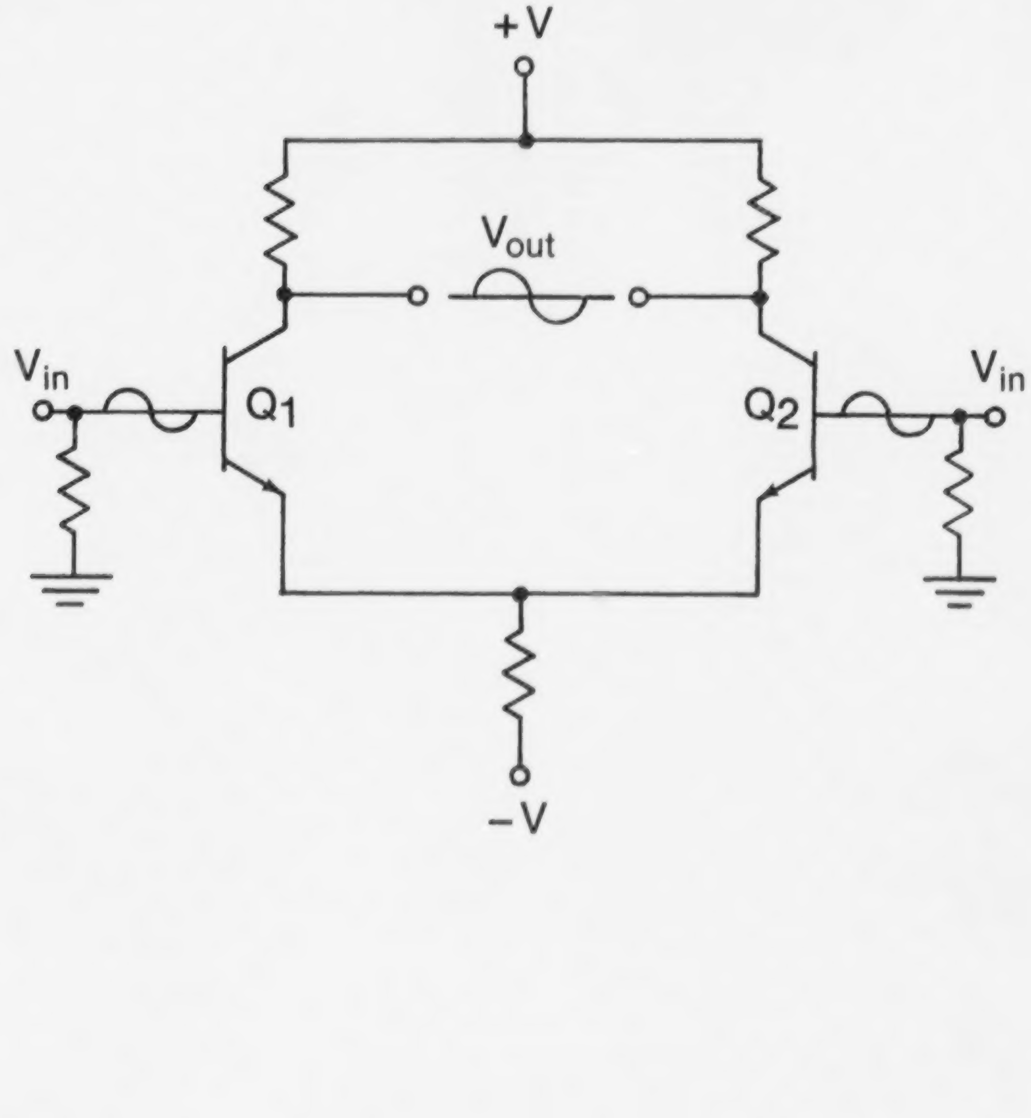
Single-Input, Single Output Differential Amplifier


+V
Output
Input
Q_1
Q_2
–V

Single-Input, Differential-Output Differential Amplifier


+V
V_{out_1}
V_{out_2}
V_{in}
Q_1
Q_2
−V

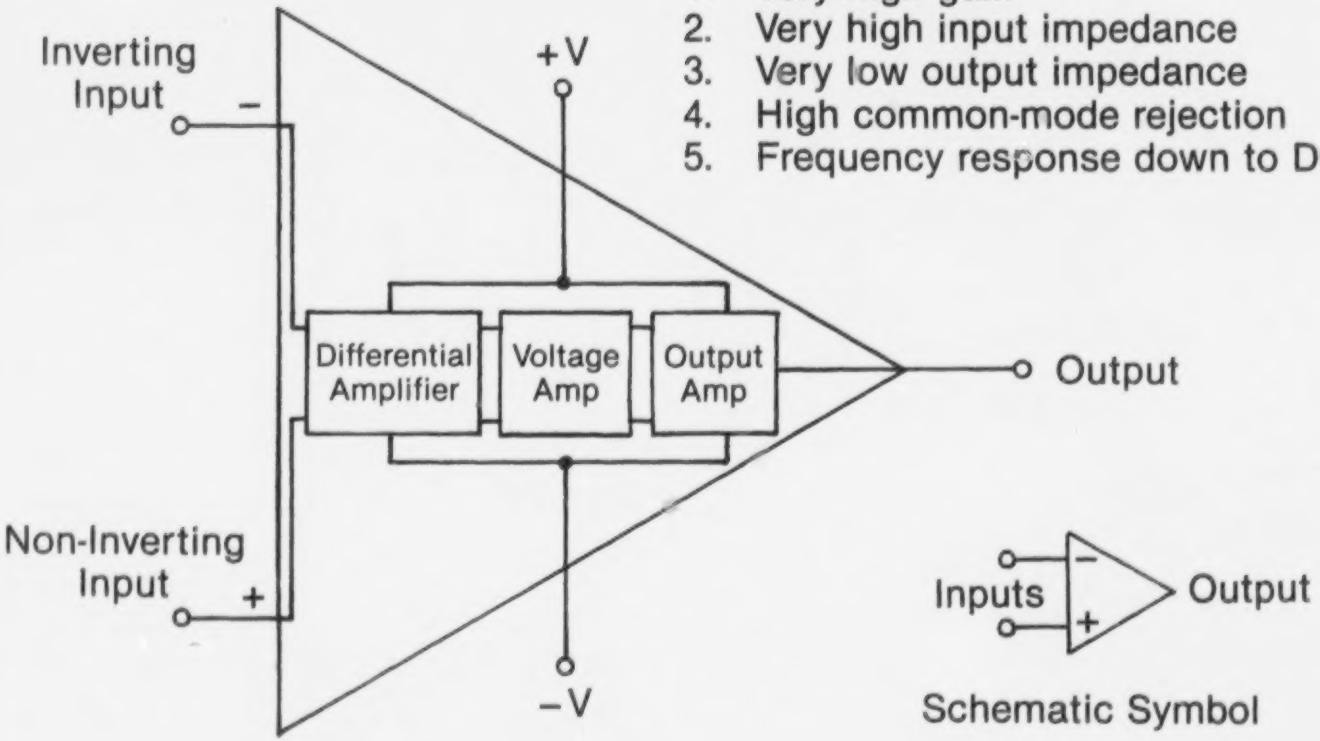
Differential-Input, Differential-Output Differential Amplifier


+V
V_{out}
V_{in}
Q_1
Q_2
V_{in}
−V

Operational Amplifier

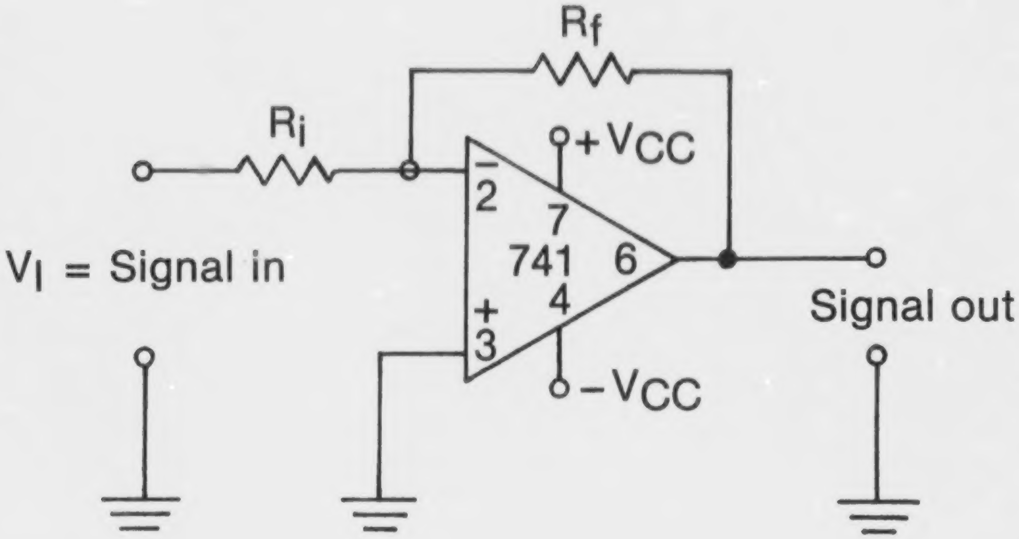
Desirable Characteristics

1. Very high gain
2. Very high input impedance
3. Very low output impedance
4. High common-mode rejection
5. Frequency response down to DC


Inverting Input
−
Non-Inverting Input
+
+V
−V
Differential Amplifier
Voltage Amp
Output Amp
Output
Inputs
−
+
Output

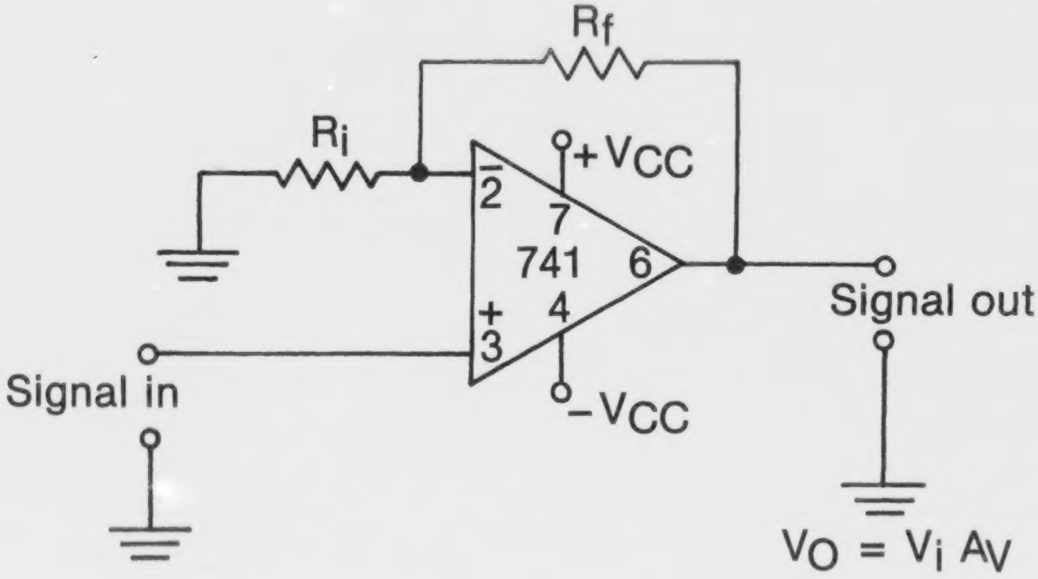
Schematic Symbol

Inverting Amplifier


R_f
R_i
+V_CC
−
2
7
741
6
4
+
3
−V_CC
V_I = Signal in
Signal out

$$A_V = \frac{-R_f}{R_i}$$

Noninverting Amplifier



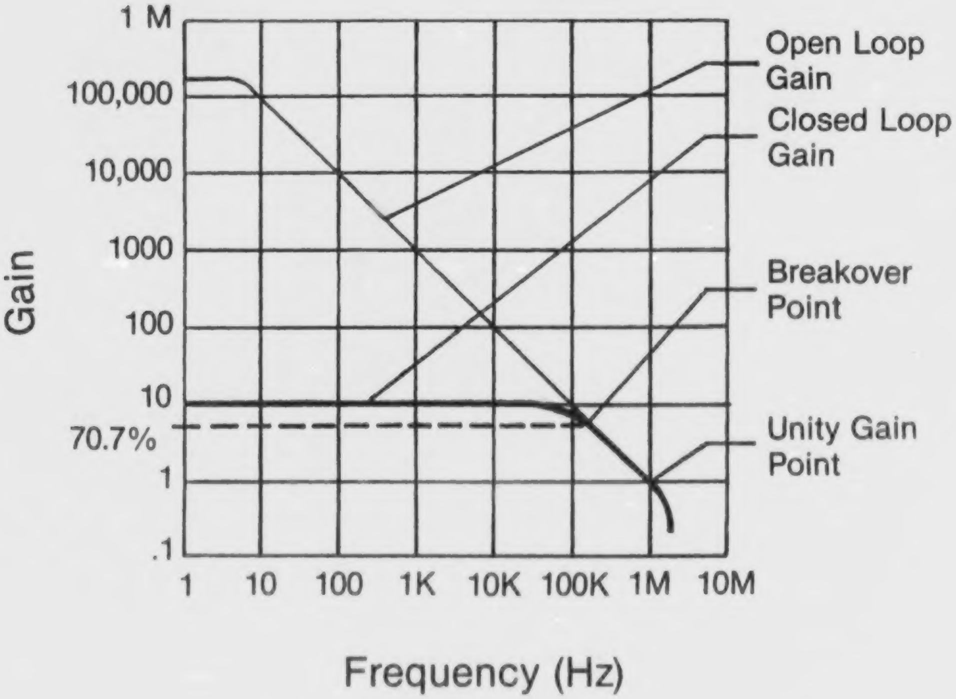
Rf
Ri
+VCC
2
7
741
6
+
4
3
–VCC
Signal in
Signal out

$V_O = V_i A_V$

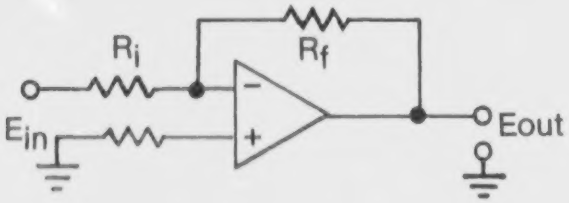
$$A_v = \frac{R_i + R_f}{R_i} = 1 + \frac{R_f}{R_i}$$

TM 11

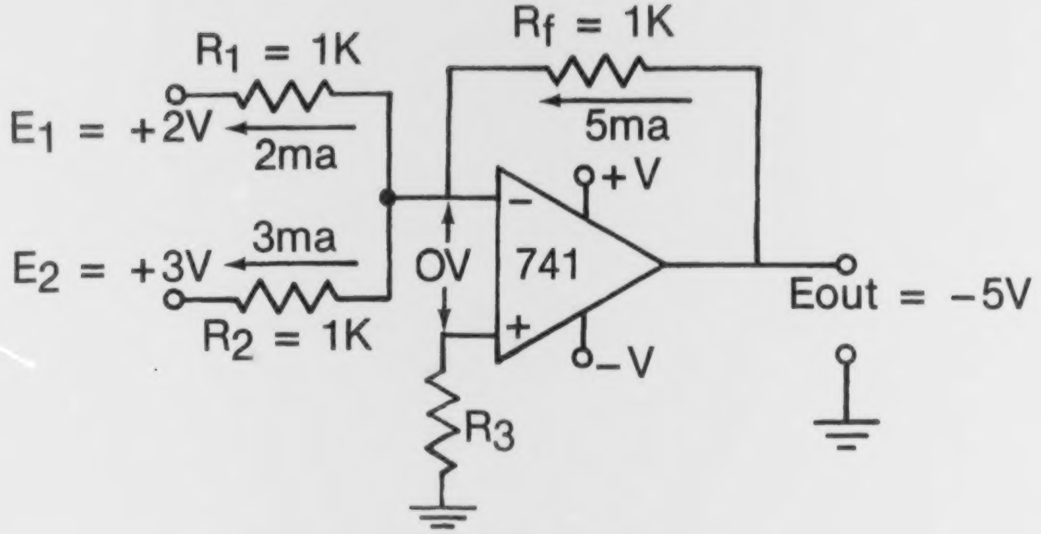
Gain Versus Bandwidth



R_i	R_f	Gain	Bandwidth	R_{in}
10K	10K	1	1MHZ	10K
10K	1K	10	100KHZ	1K
100K	1K	100	10KHZ	1K
100K	100K	1000	1KHZ	100K



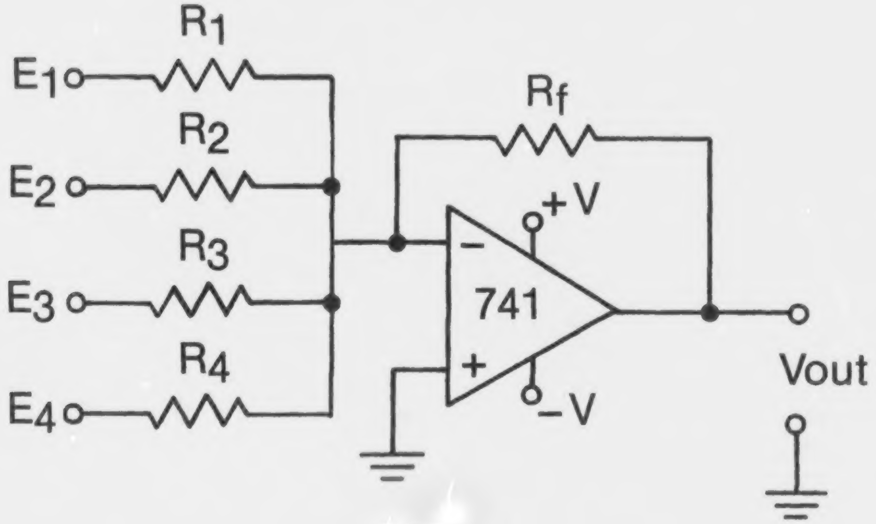
Two-Input Summing Amplifier


R_1 = 1K
E_1 = +2V
2ma
R_f = 1K
5ma
+V
E_2 = +3V
3ma
R_2 = 1K
OV
741
−
+
−V
R_3
Eout = −5V

$$E_{out} = -(E_1 + E_2)$$

(for equal resistors)

Four-Input Summing Amplifier



R1
E1
R2
E2
R3
E3
R4
E4
Rf
+V
741
−V
Vout

$R_1 = 8K,\ R_2 = 4K,\ R_3 = 2K,\ R_4 = 1K,\ R_f = 8K$

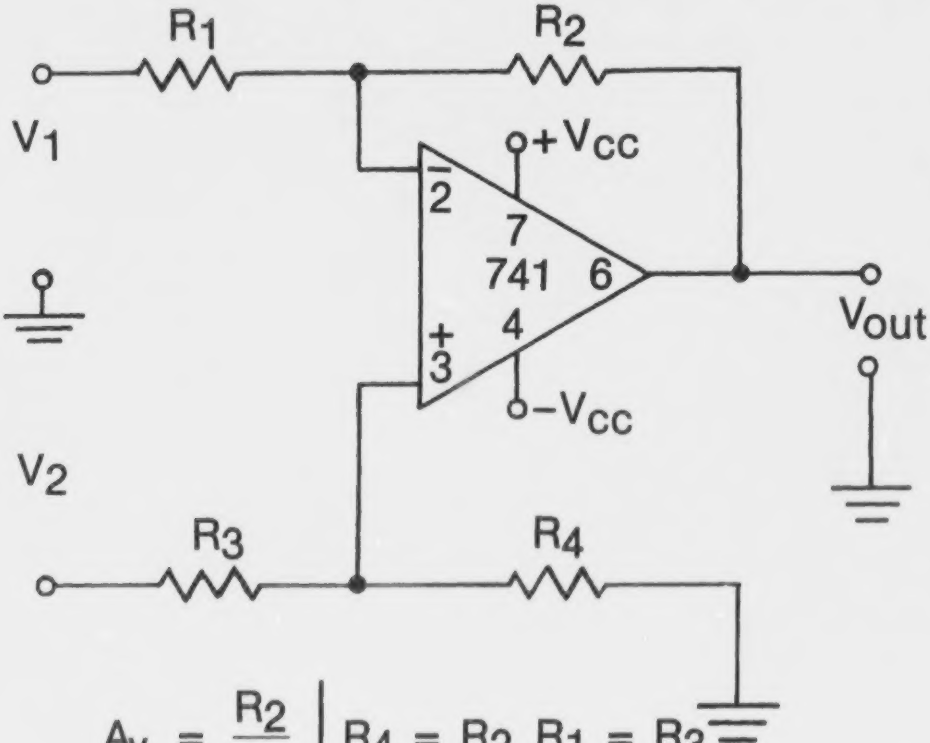
$$E_{out} = -\left(\frac{R_f}{R_1}E_1 + \frac{R_f}{R_2}E_2 + \frac{R_f}{R_3}E_3 + \frac{R_f}{R_4}E_4\right)$$

(for unequal resistors)

250

TM 14

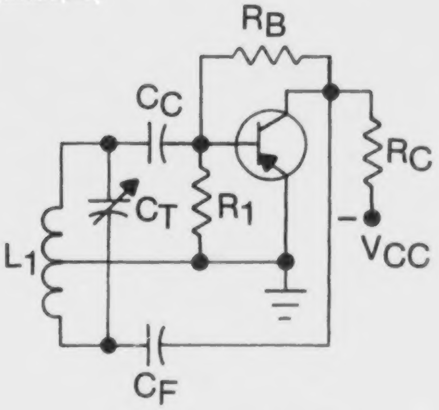
Differential DC Amplifier


R1
R2
V1
+Vcc
−
2
7
741
6
Vout
4
+
3
−Vcc
V2
R3
R4

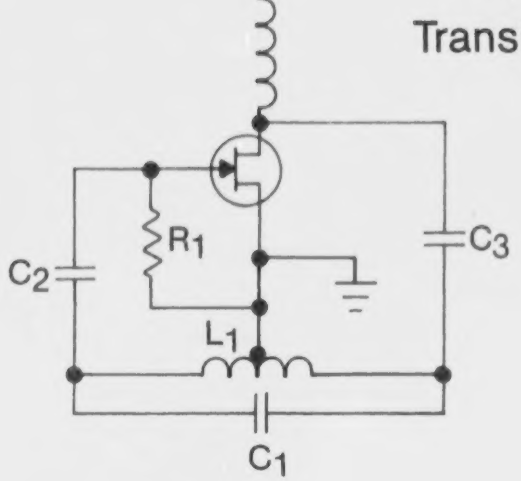
$A_V = \frac{R_2}{R_1}$ | $R_4 = R_2$ $R_1 = R_3$

$$V_{out} = \frac{R_2}{R_1}(V_2 - V_1)$$

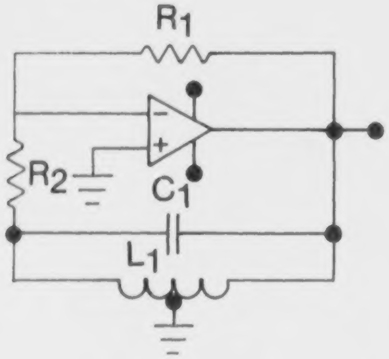
Hartley Oscillators


R_B
C_C
R_C
C_T
R_1
L_1
$-$
V_{CC}
C_F

Transistor Type


$+V_{CC}$
R_1
C_2
C_3
L_1
C_1

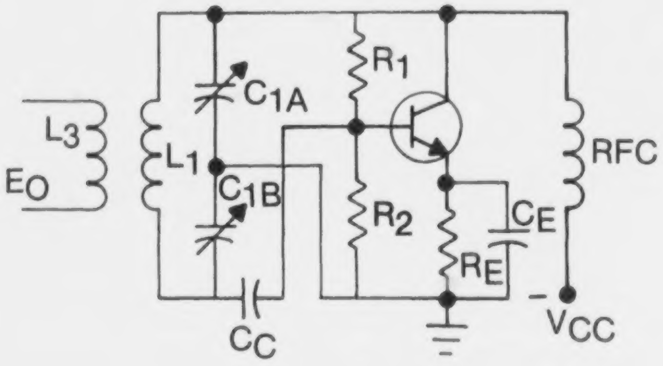
Fet-Type



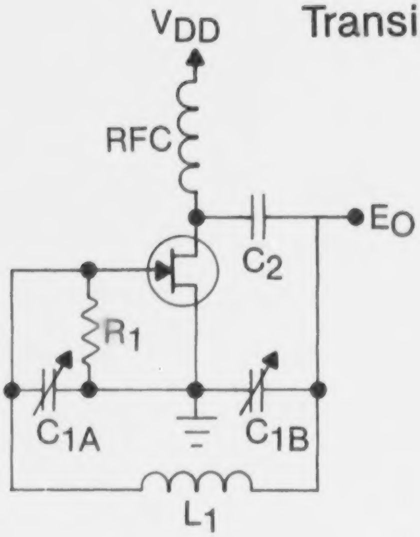
Op-Amp Type

- Inductive Feedback Is Utilized
- Amplitude Of Feedback Determined By Ratio Of Turns Between L_{IA} And L_{IB}
- Phase Of Feedback Determined By Direction Of Windings In Coils
- LC Type Frequency Determining Network

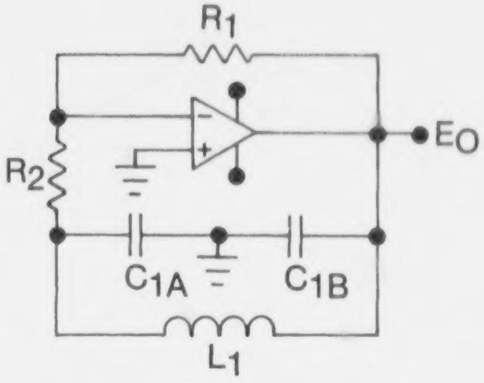
Colpitts Oscillators


L3
EO
L1
C1A
C1B
R1
R2
RFC
CE
RE
CC
-
VCC

Transistor Type


VDD
RFC
EO
C2
R1
C1A
C1B
L1

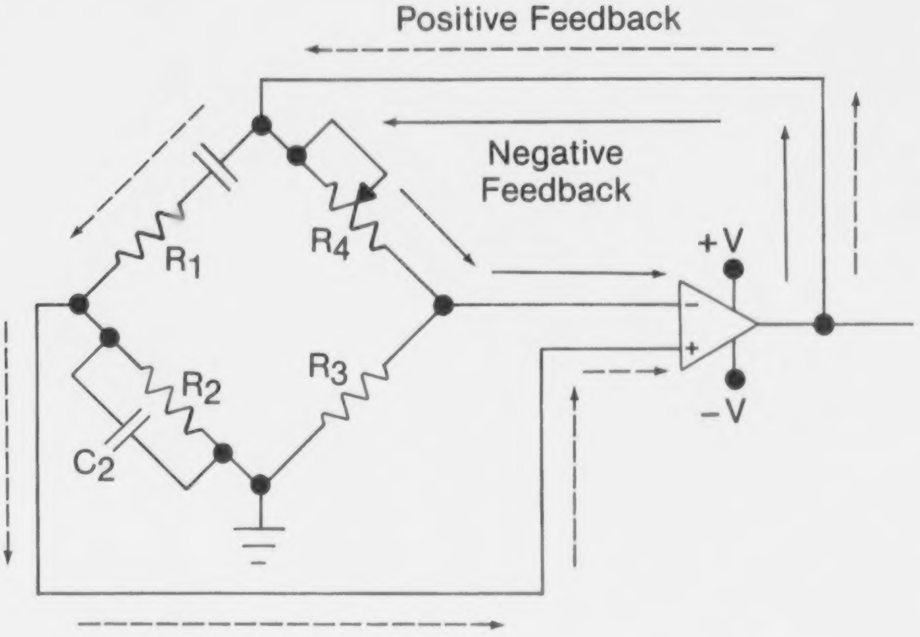
Fet Type


R1
EO
R2
C1A
C1B
L1

Op-Amp Type

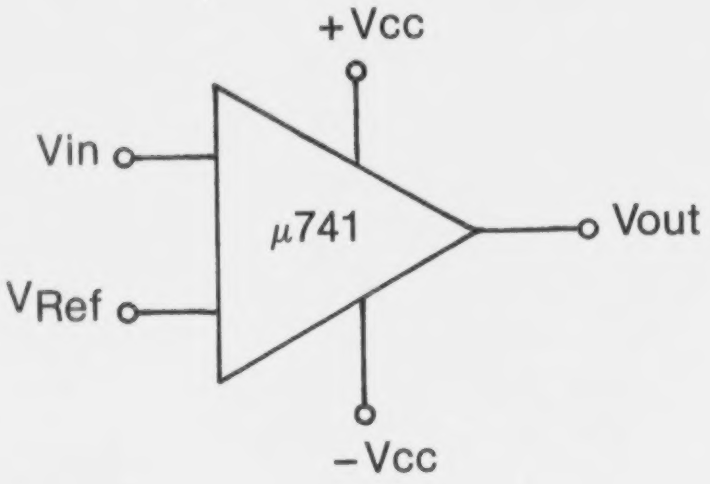
- Capacitive Feedback
- Ratio Between C_{1A} And C_{1B} Determines Amplitude Of Feedback
- Frequency Determined By LC Tank Circuit

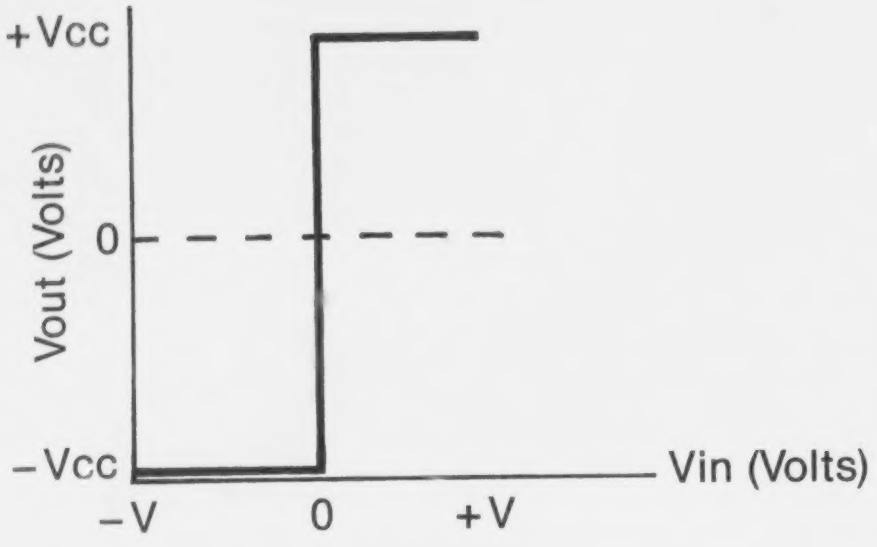
Wein-Bridge Oscillator


Positive Feedback
Negative Feedback
R1
R4
+V
R2
R3
C2
–V
–
+

- C_1, R_1, and C_2, R_2 Form The Frequency Determining Network
- R_3 and R_4 Develop The Degenerative Feedback

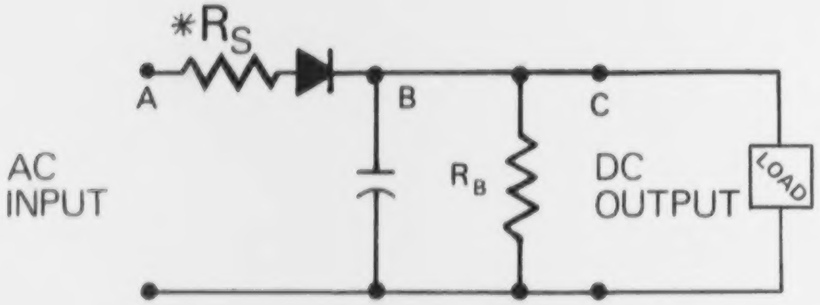
Simplified Comparator Circuit


+Vcc
Vin
μ741
Vout
VRef
−Vcc

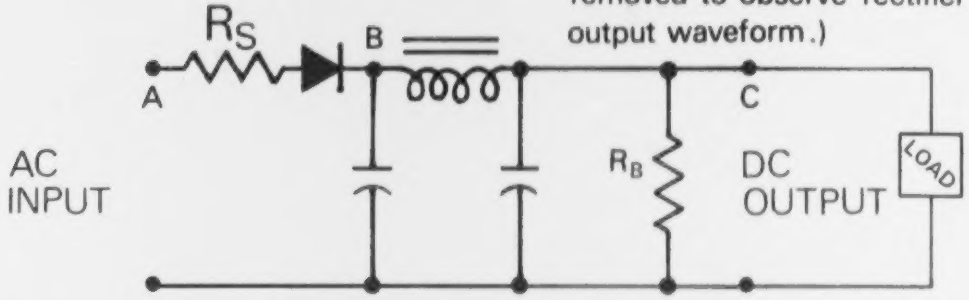


Ideal Comparator Output

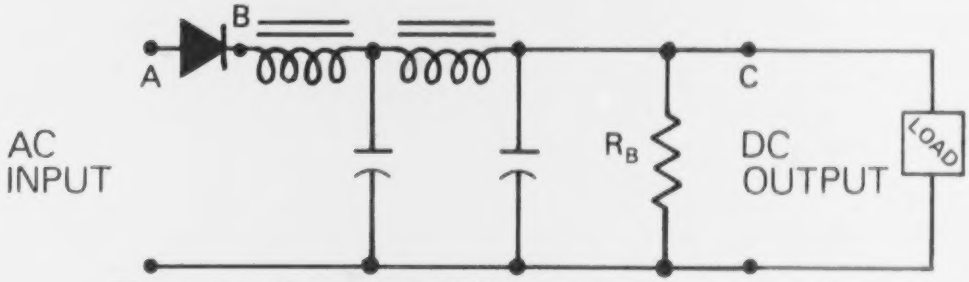
Basic Filter Configurations


*R_S
A
B
C
AC INPUT
R_B
DC OUTPUT
LOAD

Capacitor Filter (NOTE- Capacitor must be removed to observe rectifier output waveform.)


R_S
A
B
C
AC INPUT
R_B
DC OUTPUT
LOAD

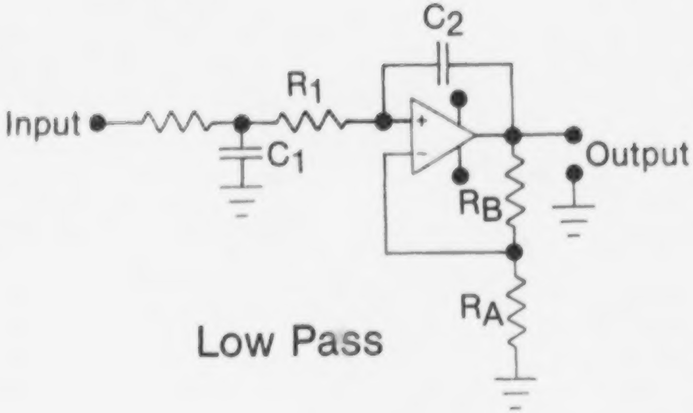
PI-Section Filter


B
A
C
AC INPUT
R_B
DC OUTPUT
LOAD

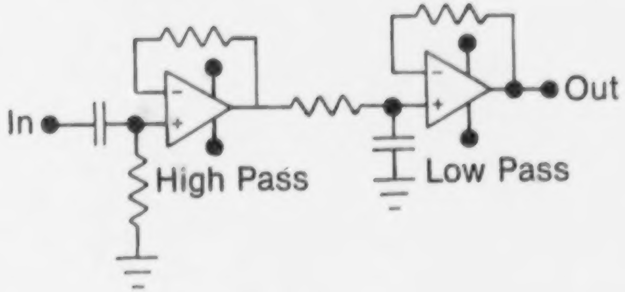
Two L-Section Filter

* (NOTE- R_S in series with diode limits initial surge of current due to capacitor and is called a surge resistor.)

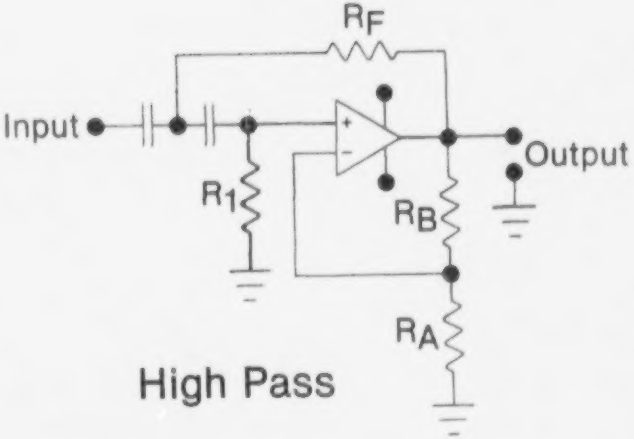
Active Filters


C2
R1
Input
C1
Output
RB
RA

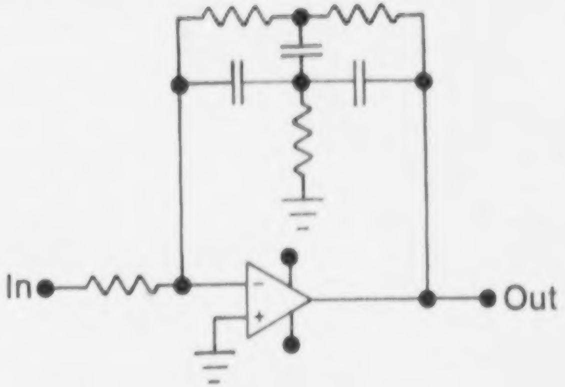
Low Pass


In
Out
High Pass
Low Pass

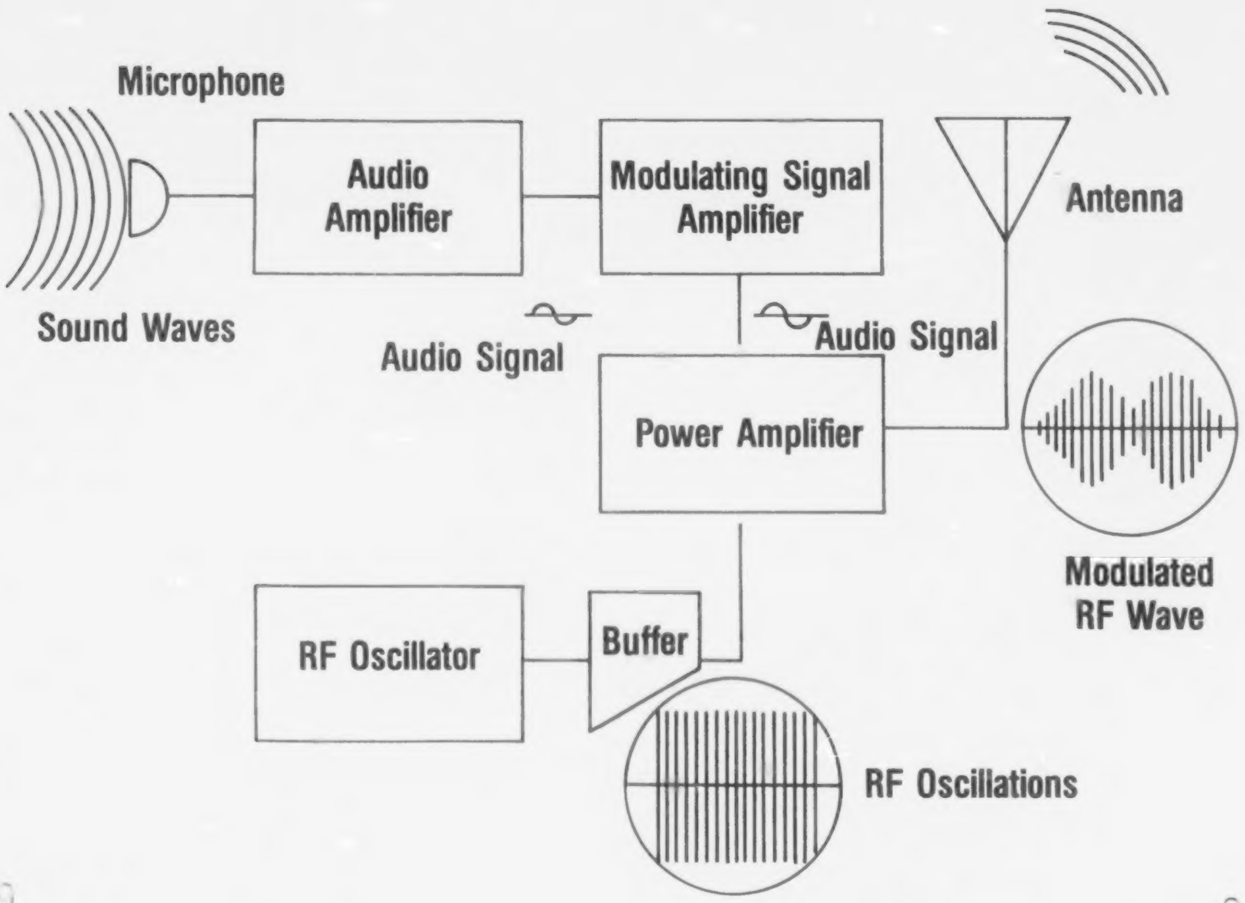
Band Pass


RF
Input
Output
R1
RB
RA

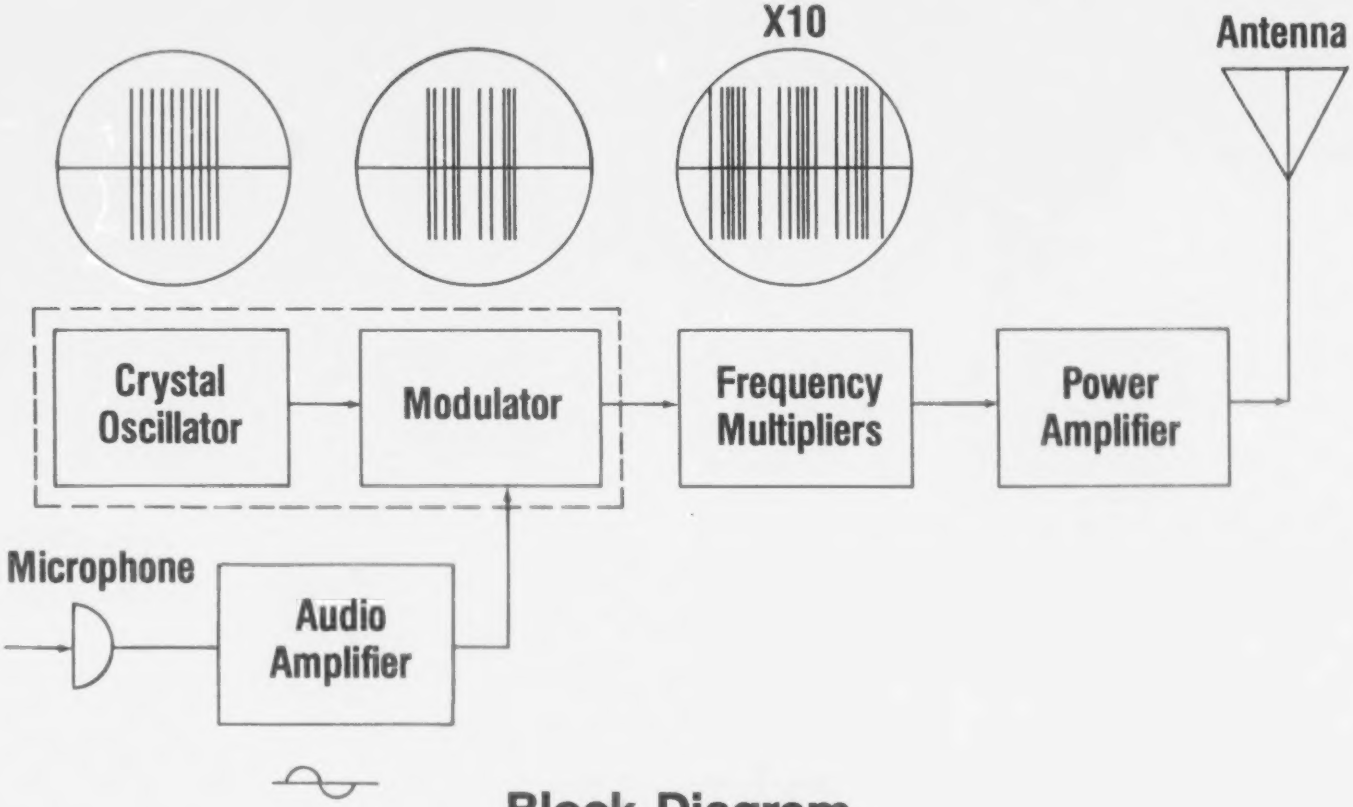
High Pass



AM Transmitter


Microphone
Sound Waves
Audio Amplifier
Modulating Signal Amplifier
Audio Signal
Audio Signal
Antenna
Power Amplifier
Modulated RF Wave
RF Oscillator
Buffer
RF Oscillations

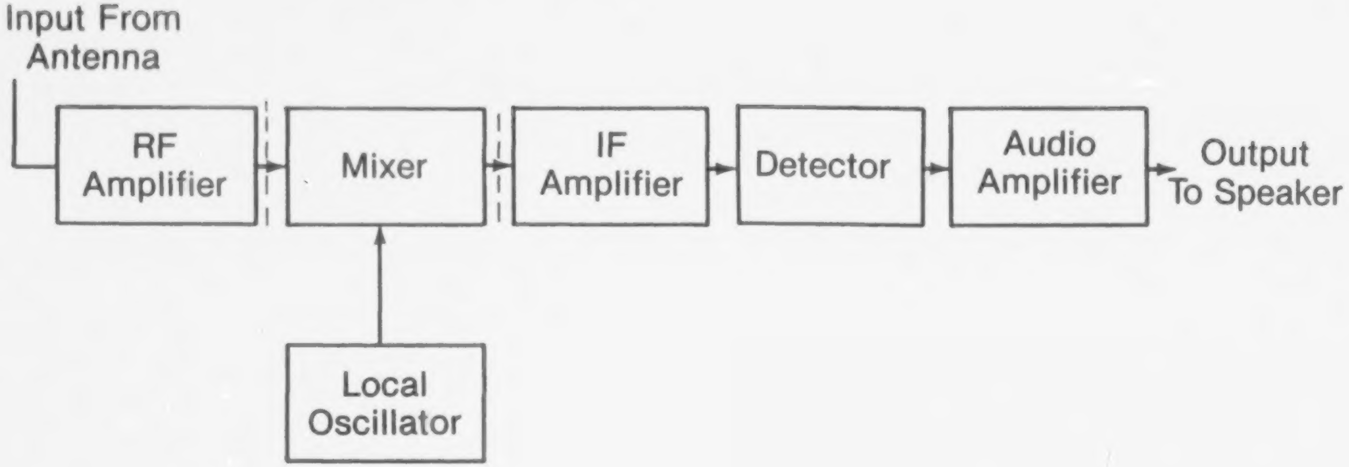
FM Transmitter


X10
Antenna
Crystal Oscillator
Modulator
Frequency Multipliers
Power Amplifier
Microphone
Audio Amplifier

Block Diagram

General Electronics Technician: Semiconductor Devices and Circuits, Unit 2
Teacher Page 101

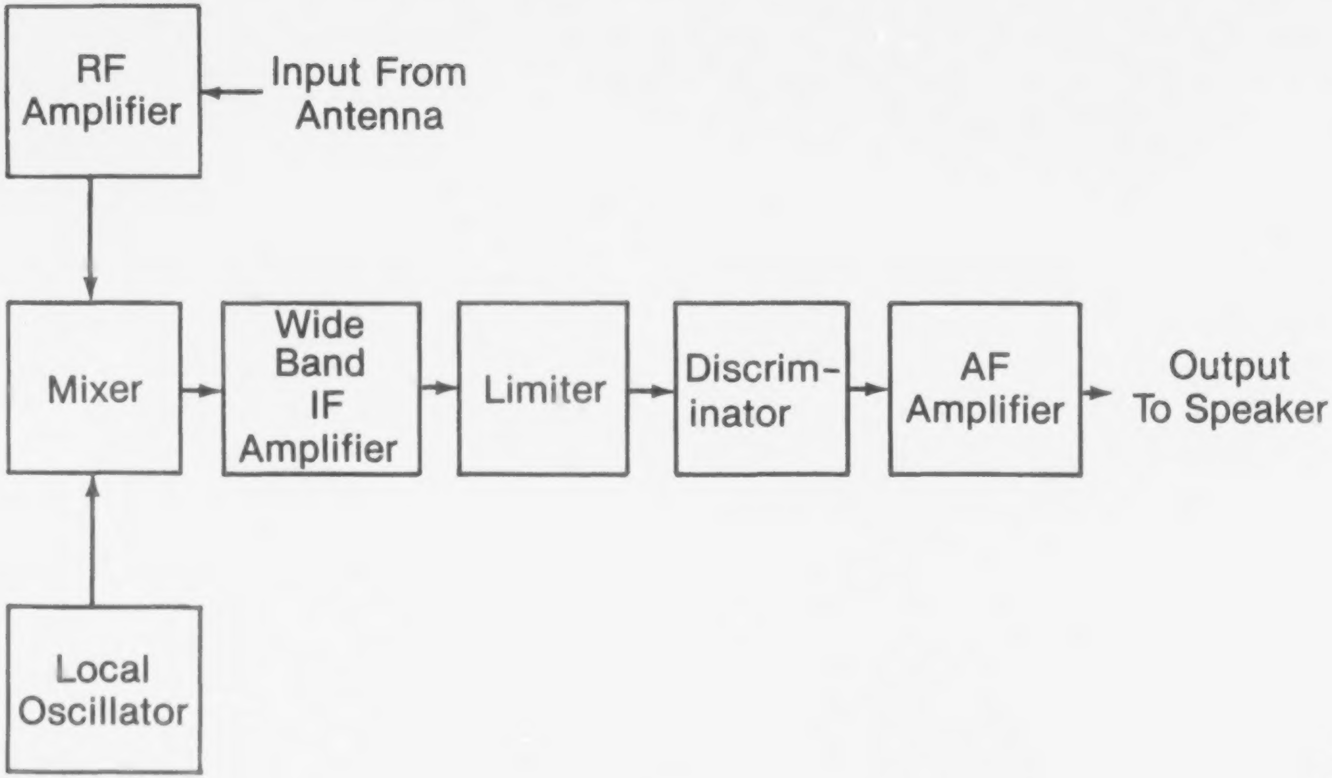
AM Superheterodyne Receiver Block Diagram


Input From Antenna
RF Amplifier
Mixer
IF Amplifier
Detector
Audio Amplifier
Output To Speaker
Local Oscillator

General Electronics Technician Semiconductor Devices and Circuits, Unit 2
Teacher Page 103

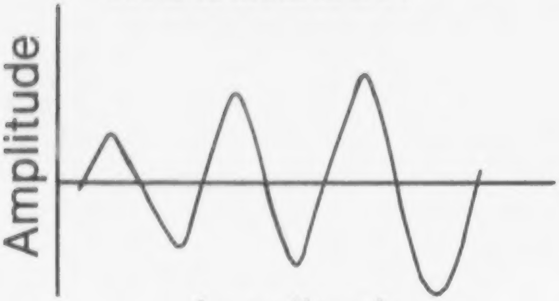
TM 24

FM Broadcast Receiver Block Diagram

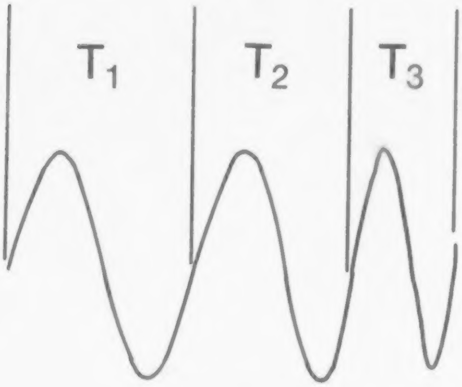

RF Amplifier
Input From Antenna
Mixer
Wide Band IF Amplifier
Limiter
Discrim-inator
AF Amplifier
Output To Speaker
Local Oscillator

General Electronics Technician. Semiconductor Devices and Circuits, Unit 2
Teacher Page 105

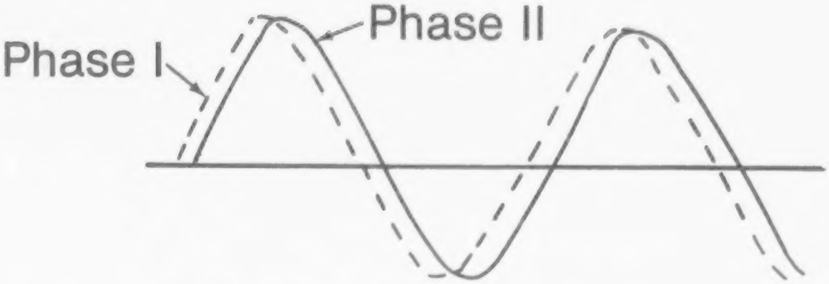
Modulation



Amplitude

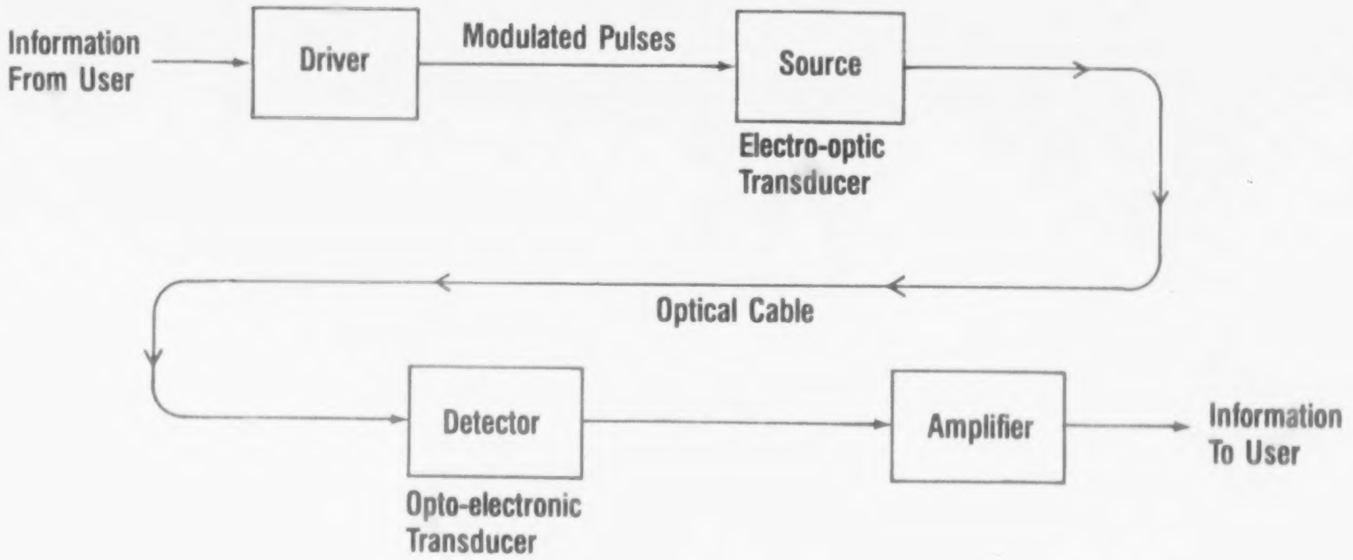


Frequency

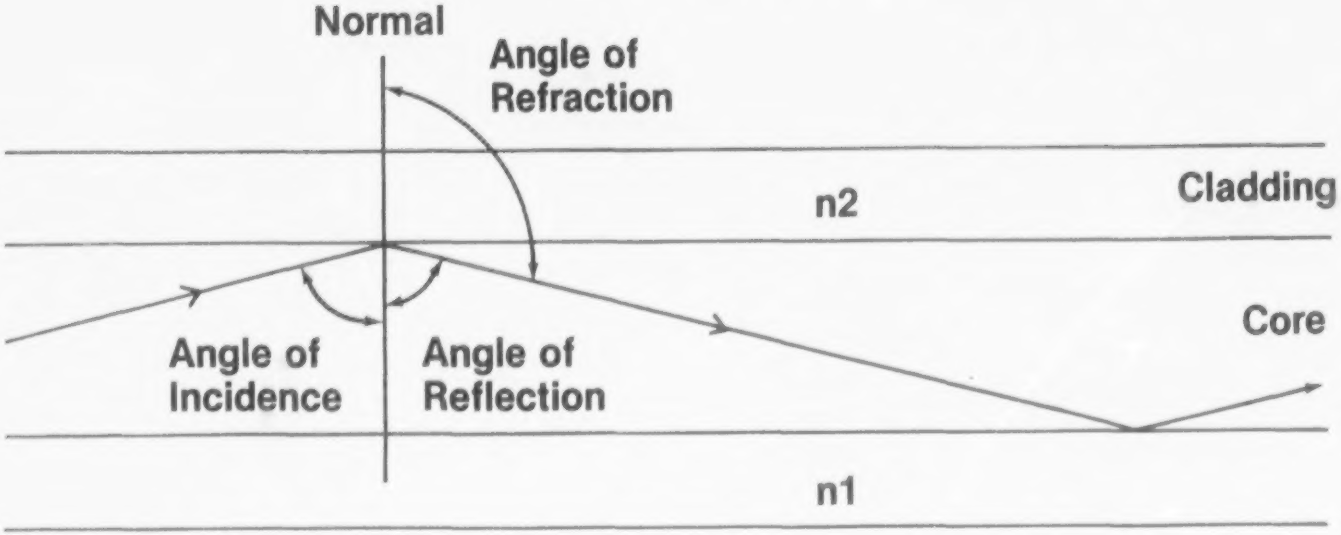

Phase I
Phase II

Phase

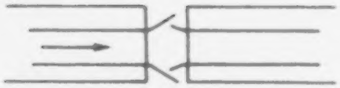
Optical Communications System


Information From User
Driver
Modulated Pulses
Source
Electro-optic Transducer
Optical Cable
Detector
Opto-electronic Transducer
Amplifier
Information To User

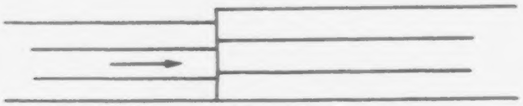
Optical Fiber Light Transmission


Normal
Angle of Refraction
Cladding
n2
Core
Angle of Incidence
Angle of Reflection
n1

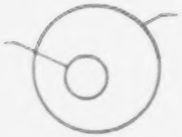
Loss Factors of Fiber Optic Connectors



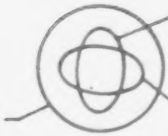
NA Mismatch



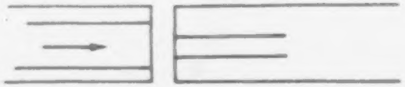
Cladding Diameter Mismatch


Core
Cladding

Concentricity


Core 1
Claddings
Core 2

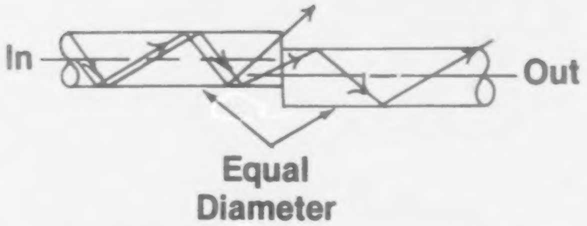
Ellipticity (Ovality)



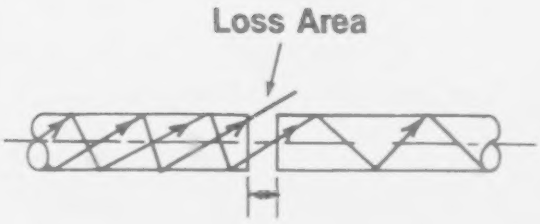
Core Diameter Mismatch

General Electronics Technician: Semiconductor Devices and Circuits, Unit 2
Teacher Page 113

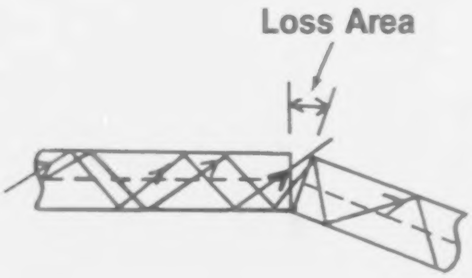
Loss Factors of Fiber Optic Connectors (Continued)


In
Out
Equal
Diameter

Lateral Displacement



End/Gap Displacement



Angular Misalignment

Refraction Indices

Material	Index	Light Velocity (km/s)
Vacuum	1.0	300,000
Air	1.0003	300,000
Water	1.33	225,000
Fused quartz	1.46	205,000
Glass	1.5	200,000
Diamond	2.0	150,000
Silicon	3.4	88,000
Gallium arsenide	3.6	83,000

276

TM 31

Power Supplies
Unit 3

Suggested Activities

Instructional Plan

Preparation

- Review unit and plan presentation. Study the specific objectives to determine the order in which you will present the objectives.

  Review the unit introduction and teaching suggestions included in the delivery and application section below, and plan classroom activities. Also note the suggestions for media and supplemental materials.

  Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.

- Obtain films, videotapes, and other media to supplement instruction of this unit. See ordering information in the suggested resources section.

- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only and should be used with objectives as indicated below.

  TM 1—The Transformer (Objective 2)
  TM 2—Half-Wave Rectifier Circuits (Objective 5)
  TM 3—Half-Wave Rectifier Output (Objective 5)
  TM 4—Conventional Full-Wave Rectifier (Objective 6)
  TM 5—Bridge Rectifier (Objective 7)
  TM 6—Combination Power Supplies(Objective 8)
  TM 7—Half-Wave Voltage-Doubler Circuit (Objective 11)
  TM 8—Full-Wave Voltage-Doubler Circuit(Objective 11)
  TM 9—Voltage Tripler (Objective 11)
  TM 10—Simple Regulated Power Supply (Objective 12)
  TM 11—Regulated Power Supply Block Diagram (Objective 12)
  TM 12—Feedback Regulator (Objective 14)
  TM 13—Switching Regulator (Objective 15)
  TM 14—Load Protection (Objective 16)

- Select teacher components (written test, unit evaluation form) you want to distribute to your students. Copy and prepare these components for distribution.

- Prepare classroom. Put up posters and charts and display articles and other references related to the objectives of this unit.

Suggested Activities

Delivery and Application

Unit Introduction

- Discuss unit and specific objectives.
- Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets and job sheets. Review with students the criteria for evaluation of each of these activities.

Teaching Suggestions

The skill areas appearing in bold-face type in the teaching suggestions refer to the academic and workplace skills identified in *What Work Requires of School: A SCANS Report for America 2000* and *Workplace Basics: The Skills Employers Want*. These have been adapted by MAVCC.

- Provide the students with examples of various types of power supplies consistent with the definition in Objective 1—that is, generators, batteries, rectifiers, transformers, etc. Then show the kinds of power supplies more commonly found in electronic equipment. Have the class discuss why ICs, diodes and transistors, and similar circuits would be used in electronic equipment as opposed to transformers, generators, etc. Display schematics of electronic equipment power supplies and relate component functions to those described in the information sheet and to the larger power supply devices that you displayed. Have students brainstorm what would constitute a perfect power supply. Get them to recall what they know about rectifiers and voltage regulators to come up with the ideal characteristics. **(Listening; seeing things in the mind's eye; applying technology; creative thinking; reasoning)**
- Demonstrate key concepts in the unit, such as ripple, regulation, and circuit protection. Use actual equipment to show what happens when there is too much ripple in the supply power. For example, disable a filter capacitor and demonstrate the equipment operation. Be aware of relating such symptoms to the steps for troubleshooting that are presented in the unit. Have the students predict how systems will be affected by given problems related to these concepts. **(Listening; science; applying technology; adapting to the organization's goals and values; monitoring systems)**

Suggested Activities

- Demonstrate troubleshooting and use the demonstration as an opportunity to explain why power supply defects are so likely to be noticeable. Provide the students with a number of problems and progressively increase their roles in determining how best to troubleshoot the problem and in offering ideas as to the causes. **(Listening; seeing things in the mind's eye; applying technology; selecting tools and procedures; troubleshooting)**

Evaluation

- Discuss with students the use of the Unit Evaluation Form. Explain the rating scale that will be used for student evaluation.
- Copy written test and give to students as pretest. Record pretest score on the Unit Evaluation Form.
- Evaluate assignment sheets. See the evaluation criteria listed at the top of each assignment sheet and the component "Answers to Assignment Sheets."
- Evaluate job sheets. See the evaluation criteria listed at the top of each job sheet.
- Give and evaluate written test.
- Compile written-test, assignment-sheet, and job sheet scores on the Unit Evaluation Form. Include any additional assignments.
- Measure competency gains by comparing written pretest scores with posttest scores.
- Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.
- Reteach and retest as required.

Instructions for Evaluating Student Performance

- When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Suggested Activities

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

1 — Skilled—Can perform job with no additional training.
2 — Moderately skilled—Has performed job during training program; limited additional training may be required.
3 — Limited skill—Has performed job during training program; additional training is required to develop skill.
4 — Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Suggested Resources

Resources Used in Developing This Unit

- *Basic Electronics.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1987.
- *Communications Electronics.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1988.
- Davidson, Homer L. *Troubleshooting and Repairing Compact Disc Players.* 2nd Ed. New York, New York: TAB Books, 1994.
- *Family Medical Guide.* New York, NY: Better Homes and Gardens Books, Meredith Corporation, 1993.
- *General Electronics Technician.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1987.
- *Graphic Symbols for Electrical and Electronics Diagrams.* New York: Institute of Electrical and Electronics Engineers, Inc., 1975.
- *Home Electronics.* Alexandria, Virginia: Time-Life Books, 1988.

- Roehrig, Guido and Ulrich Schueller. *Upgrading and Maintaining Your PC*. Grand Rapids, Michigan: Abacus, 1991.
- Schuler, Charles A. *Electronics Principles and Applications*. 4th edition. New York: Glencoe Division, Macmillan/McGraw-Hill School Publishing Company, 1994.

Supplemental Resources

Print Media

- Data books and resource sheets from a variety of electronics components and equipment manufacturers.
- *Electronics Workmanship Standards*. Omni Corporation.
- *Workmanship Standards*. Marietta, Georgia: Martin-Marietta Corporation.
- *Rework and Repair for Electronics*. Laurel, Maryland: Pace Incorporated.

Non-print Media

- *The Universal Systems Model*. This 16-minute videotape can be used in helping students learn to approach troubleshooting from a systems level. It introduces the concepts of open- and closed-loop systems and presents procedures for technological problem-solving. Available from: Bergwall Productions, Inc.,
- *Controlling Systems*. This program discusses macro- and microsystems and defines feedback. The discussions of monitoring devices, sensors, transducers, and comparators are basic and not overly technical and can be helpful in expanding the students' perspective of systems approaches. Available from: Bergwall Productions, Inc.

Power Supplies
Unit 3

Answers to Assignment Sheets

Assignment Sheet 1—Calculate Average Voltages

1. 13.5 volts
2. 180 volts
3. 108 volts
4. 10.2 volts
5. 15.3 volts

Assignment Sheet 2—Calculate RMS Values

1. 9.6 volts
2. 26.7 volts
3. 13.1 volts
4. 13.8 volts
5. 25.7 volts

Assignment Sheet 3—Calculate Ripple Factors and Percent Regulation

1.
    a. 33%
    b. 5.6%
2.
    a. 0.33%
    b. 8.7%
3.
    a. 6.7%
    b. 9.1%
4. 2.4%
5. 12%
6.
    a. 11.3%
    b. 7.7%

Power Supplies
Unit 3

Answers to Written Test

1. a. 10
   b. 8
   c. 15
   d. 12
   e. 7
   f. 4
   g. 9
   h. 2
   i. 5
   j. 11
   k. 14
   l. 1
   m. 6
   n. 3
   o. 13

2. a. 6
   b. 2
   c. 1, 3
   d. 5
   e. 4
   f. 8
   g. 7

3. a. 2
   b. 8
   c. 7
   d. 4
   e. 3
   f. 5
   g. 6
   h. 9
   i. 1

4. Provides both positive and negative DC output

5. a. One-half of each
   b. Equal to
   c. May be either positive or negative
   d. 0.707
   e. 1.414
   f. 0.318

6. a. The full
   b. Equal to twice
   c. Direction
   d. 0.707
   e. 1.414
   f. 0.637

7. a. The full
   b. Equal to twice
   c. Diodes
   d. 0.707
   e. 1.414
   f. 0.637

8. a. B
   b. F

9. a. 2
   b. 1
   c. 3

Answers to Written Test

10. $$\% \text{ ripple} = \frac{E_{rms}}{E_{avg}} \times 100$$

11. a. Half-wave voltage doubler
    b. Full-wave voltage doubler
    c. Voltage tripler

12. $$\text{Regulation} = \frac{\Delta V}{V_{full\ load}} \times 100$$

13. a. Series
    b. Shunt
    c. Series
    d. Shunt
    e. Shunt
    f. Series

14. a. The DC reference voltage is generally collected through a zener diode and fed to the error detector.
    b. The sampling and adjustment circuit is usually a voltage divider connected across the output branches and provides feedback to the error detector.
    c. The error detector compares the reference input signal and the sampled output signal and provides an output to the regulator transistor.
    d. The error voltage amplifier amplifies the output of the error detector and routes the signal to the regulator transistor.
    e. The error voltage controls the conductivity of the regulator transistor to adjust input signal flow in response to the sampled output.
    f. The feedback regulator may consist of discrete components, discrete and linear integrated components, or a single IC.

15. a. Efficiency
    b. Inverting

16. a. Current limiting circuit
    b. Crowbar circuit

17. a. 5
    b. 7
    c. 2
    d. 1
    e. 4
    f. 6
    g. 3

Power Supplies
Unit 3

Written Test

Name ______________________________ Date ___________ Score ___________

1. Match terms associated with power supplies to their correct definitions. Write the corresponding numbers on the blanks provided.

_____a. Signal with a specific or desired value in one or more characteristics (voltage, current, frequency, phasing, amplitude, etc.) to which other signals are compared

_____b. Device or circuit that provides a specific type of electrical output by transforming an electrical input or other form of energy

_____c. Controller wired parallel to the load that provides control by bypassing excessive current and by varying total current through a series resistance

_____d. Variations in the DC output of a rectifier as a result of the conversion from AC input

_____e. Comparison of the variation of a DC power supply or rectifier output expressed as a percentage of the average voltage

_____f. Process of components within a circuit by which they prevent the current from exceeding a set amount

_____g. Circuit or device that changes AC voltage into pulsating DC voltage

_____h. Inductor used in a DC power supply to reduce ripple at the output

_____i. Circuit or device used to minimize ripple in a power supply output

1. Bleeder resistor
2. Choke
3. Crowbar
4. Current limiting
5. Filter
6. Percent regulation
7. Percent ripple
8. Power supply
9. Rectifier circuit
10. Reference
11. Regulator
12. Ripple
13. Sample
14. Series regulator
15. Shunt regulator

Written Test

______j. Circuit or device that serves to keep voltage or current output at a fairly constant level despite changes in input voltage or load demand

______k. Controller wired in line with the load that provides control by varying the resistance between the power supply and the load

______l. Component connected across filter capacitors to drain charge when the circuit is de-energized

______m. Comparison of the no-load voltage to the full-load voltage of a power supply expresses as a percentage of full-load voltage

______n. Protection circuit used to turn off a power supply in the event of excessive voltage

______o. To examine a characteristic of a signal in order to compare it to other signals or defined standards

2. Match major power supply components to their general function. Write the corresponding numbers on the blanks provided.

Note: More than one component may have the same function and there may be more than one number in a blank.

______a. Regulates voltage or current and serves as a comparator for output and reference signals

______b. Rectifies AC

______c. Filters pulsating DC

______d. Steps AC voltages up or down and may provide circuit isolation

______e. Serves as controllable rectifier and often as a switch

______f. Sets reference voltage and regulates output

______g. Varies AC voltage levels by switching on and off

1. Capacitor
2. Conventional diode
3. Inductor
4. SCR
5. Transformer
6. Transistor
7. Triac
8. Zener diode

Written Test

3. Match power supply circuits to their correct purposes. Write the corresponding numbers on the blanks provided.

______a. Monitors voltages for errors and, upon error detection, produces a correction voltage for the compensating circuitry

______b. Measures portion of supply voltage to use as feedback for the control circuitry

______c. Maintains constant voltage for comparison by control circuitry

______d. Boosts correction voltage to a power level sufficient to operate the compensating circuitry

______e. Regulates the supply output

______f. Reduces ripple and noise

______g. Transforms AC into pulsating DC

______h. Changes voltage level

______i. Allows variation of output

1. Adjust circuitry
2. Comparator circuit
3. Control circuitry
4. Error amplifier
5. Filter
6. Rectifier
7. Reference circuit
8. Sample circuit
9. Voltage controller

4. State the function of a bipolar power supply.

____

____

____

5. Complete statements about the characteristics of a half-wave rectifier circuit. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

   a. Pulsating DC flows through the circuit during (one-half of each, the full) AC input cycle.

   b. The frequency of the output pulses is (equal to, equal to twice) the frequency of the AC input.

c. Output voltage polarity (is positive, is negative, may be either positive or negative) with respect to ground.

d. The effective (rms) voltage output is calculated with the equation

$E_{rms} = E_{peak} \times$ ________________

e. The peak voltage output is calculated with the equation

$E_{peak} = E_{rms} \times$ ________________

f. The average voltage output is calculated with the equation

$E_{avg} = E_{peak} \times$ ________________

6. Complete statements about the characteristics of a full-wave rectifier circuit Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. Pulsating DC flows through the circuit during (one-half of each, the full) AC input cycle.

b. The frequency of the output pulses is (equal to, equal to twice) the frequency of the AC input.

c. Output voltage polarity may be reversed by reversing the ________________ of the diodes.

d. The effective (rms) voltage output is calculated with the equation

$E_{rms} = E_{peak} \times$ ________________

e. The peak voltage output is calculated with the equation

$E_{peak} = E_{rms} \times$ ________________

f. The average voltage output is calculated with the equation

$E_{avg} = E_{peak} \times$ ________________

7. Complete statements about the characteristics of a bridge rectifier circuit. Write the missing word or phrase in the space provided or circle the correct choice given in parentheses (choice 1, choice 2).

a. Pulsating DC flows through the circuit during (one-half of each, the full) AC input cycle.

b. The frequency of the output pulses is (equal to, equal to twice) the frequency of the AC input.

c. Output voltage may be either positive or negative and depends on the arrangement of the _______________ in the bridge.

d. The effective (rms) voltage output is calculated with the equation

$E_{rms} = E_{peak} \times$ _______________

e. The peak voltage output is calculated with the equation

$E_{peak} = E_{rms} \times$ _______________

f. The average voltage output is calculated with the equation

$E_{avg} = E_{peak} \times$ _______________

8. Distinguish between the output of combination rectifier circuits. Write an "F" beside the statement below that describes the output of a full-wave/full-wave combination power supply and a "B" beside the statement that describes a full-wave/bridge combination power supply.

______a. May be used to provide two DC voltage sources.

______b. May be used to provide two outputs of opposite polarity.

9. Match basic configurations of filter circuits to their correct features. Write the corresponding numbers on the blanks provided.

______a. Uses a capacitor and inductor suitable for high current applications

______b. Uses a capacitor and resistor to provide an economical, simple filter that is acceptable where the load does not require an extremely smooth DC voltage

______c. Uses two capacitors and an inductor or two capacitors and a resistor in a low-pass arrangement to produce a fairly smooth output suitable for use with low currents

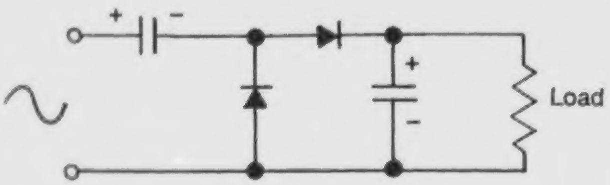
1. Capacitor filter
2. L-section filter
3. Pi-section filter

Written Test

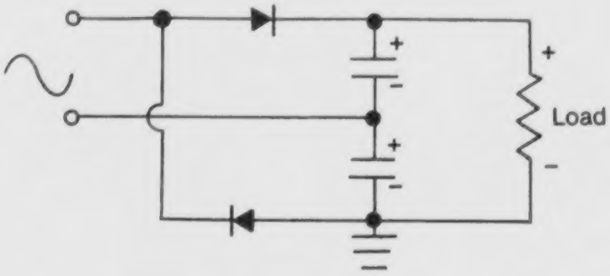
10 State the equation for calculating ripple factor.

11. Identify three basic voltage multiplier circuits.

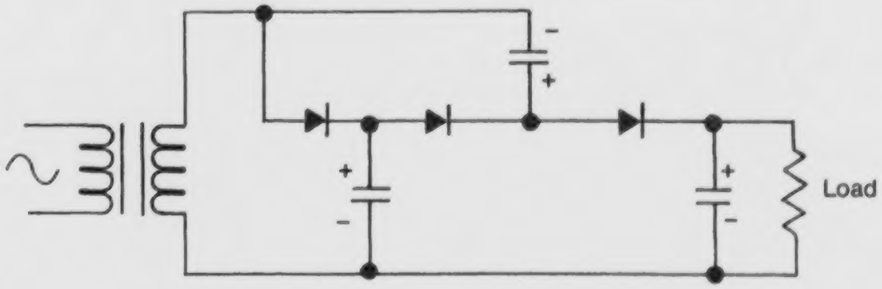
a. ______________________________



b. ______________________________



c. ______________________________



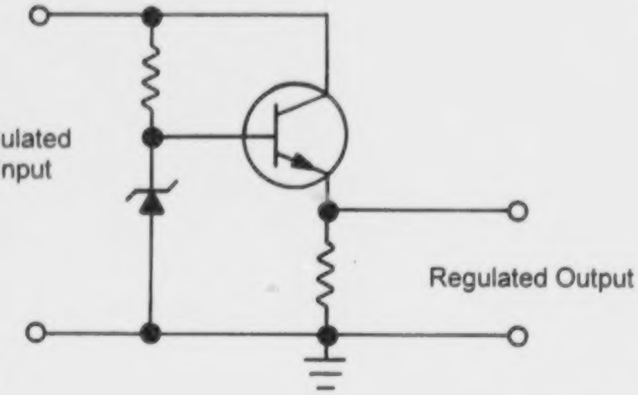
230

Written Test

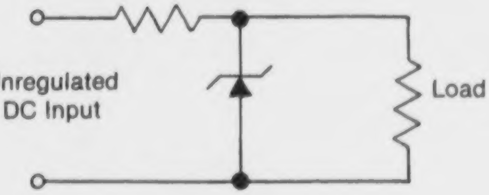
12. State the equation for calculating regulation.

13. Classify regulator configurations as series or shunt regulators.

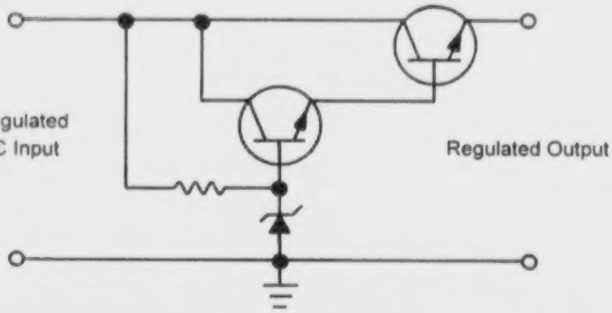
a. ______________________________


Unregulated
DC Input
Regulated Output

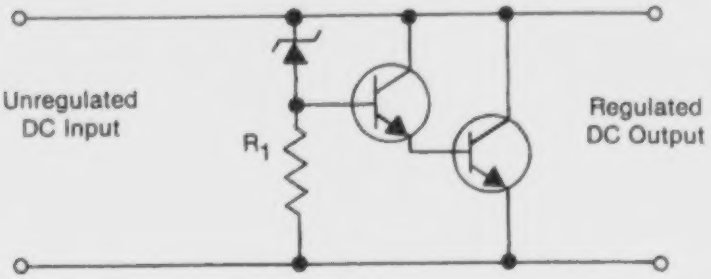
b. ______________________________


Unregulated
DC Input
Load

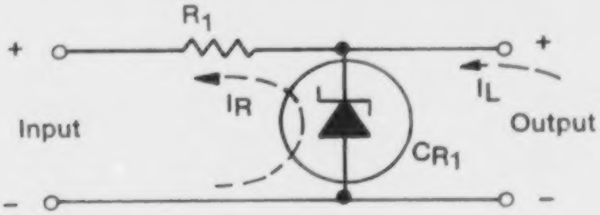
c. ______________________________


Unregulated
DC Input
Regulated Output

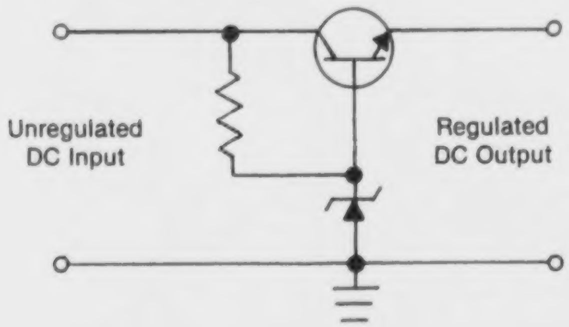
d. ______________________________


Unregulated
DC Input
R1
Regulated
DC Output

e. ______________________________


R1
+
Input
-
IR
CR1
IL
+
Output
-

f. ______________________________


Unregulated
DC Input
Regulated
DC Output

14. Describe the operation of a feedback regulator. For each key word or phrase listed below, explain how the word or phrase relates to the operation of a feedback regulator.

a. DC reference voltage--______________________________

____

b. Sampling and adjustment circuit—______________________________

____

c. Error detector—____

____

d. Error voltage amplifier—____

____

e. Regulator transistor—____

____

f. Types of components used in feedback regulators—____________________

____

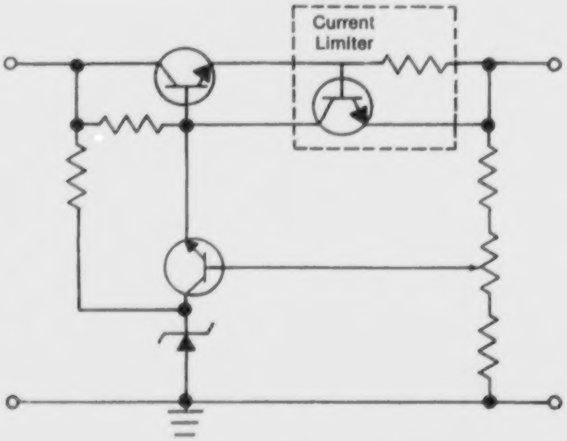
15. Complete statements about the characteristics of switching regulators.

a. The purpose of a switching regulator is to improve the ______________ of the regulator circuit by using a pulsing technique.

b. Switching regulators may be operated in step-up, step-down, or ______________ modes.

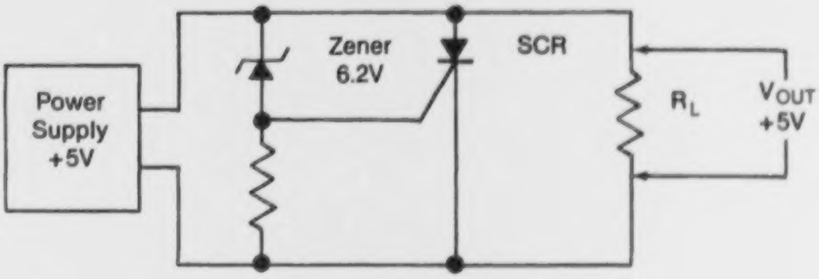
16. Identify protection circuits by their schematic diagrams.

a. ____



Written Test

b. ______________________________



17. Arrange in order the steps for troubleshooting power supplies. Write the number of each step listed below in the space provided. Begin with "1" for the first step and continue numbering the steps in order.

______a. Check all resistors for proper value.

______b. If all components are working correctly, disconnect the rectifier from the transformer and turn power on.

______c. Check filtering capacitors for charging.

______d. Disconnect the load from the power supply and check to see if the problem still exists.

______e. Check rectifier diodes for proper operation.

______f. Check transistors for proper operation.

______g. If the capacitor is not charging, disconnect one lead and check again for charging.

*Permission to duplicate this test is granted.

Power Supplies
Unit 3

Unit Evaluation Form

Student Name ________________________________ Unit Rating ______________

Assignment Sheet Ratings

Assignment Sheet 1—Calculate Average Voltages Rating _____

Comments: ____

____

Assignment Sheet 2—Calculate RMS Values Rating _____

Comments: ____

____

Assignment Sheet 3—Calculate Ripple Factors and Percent Regulation Rating _____

Comments: ____

____

Job Sheet Ratings

Job Sheet 1—Construct and Test a Voltage-Doubler Circuit Rating _____

Comments: ____

____

Job Sheet 2—Construct and Test a Capacitor Filter Circuit Rating _____

Comments: ____

____

Job Sheet 3—Construct and Test a Pi-Section Filter Circuit Rating _____

Comments: ____

____

Unit Evaluation Form

Job Sheet 4—Construct and Test a Zener Regulator Rating _____

Comments: ____

____

Job Sheet 5—Troubleshoot Power Supplies Rating _____

Comments: ____

____

Written-Test Scores

Pretest _______ Posttest _______ Other _______

Other ____

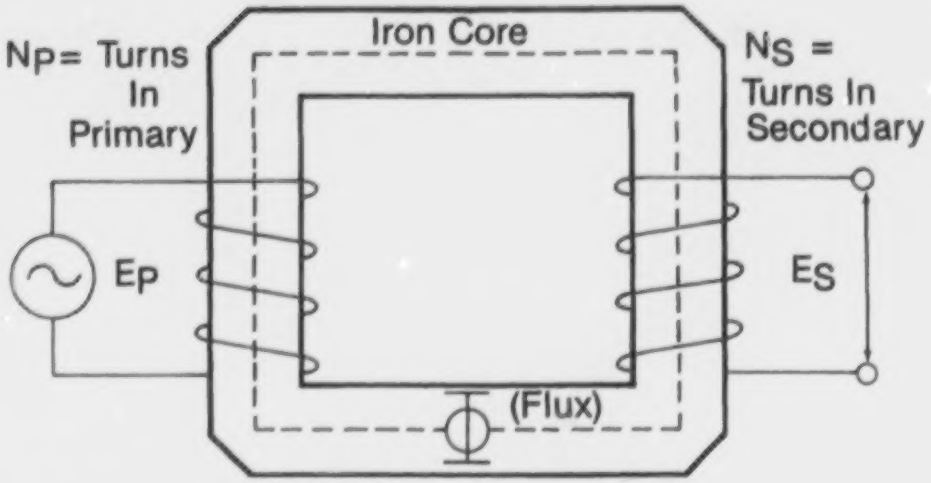
____

Teacher Signature ____________________________ Date ______________

Student Signature ____________________________ Date ______________

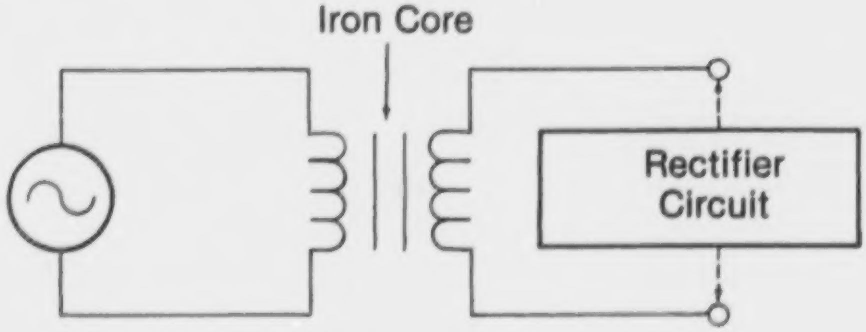
*Permission to duplicate this form is granted.

The Transformer


Iron Core
Np= Turns In Primary
Ns = Turns In Secondary
Ep
Es
(Flux)

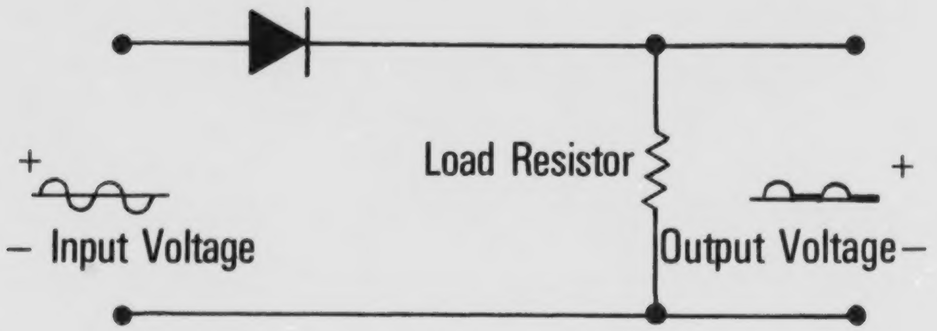
Pictorial Representation

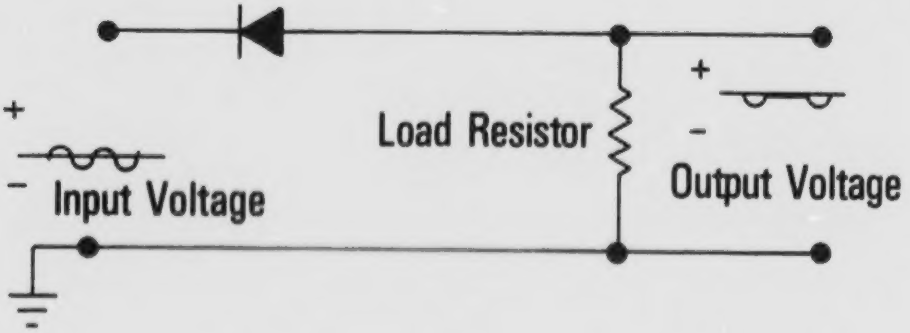
$$\frac{E_S}{E_P} = \frac{N_S}{N_P} \qquad E_S = E_P \frac{N_S}{N_P}$$


Iron Core
Rectifier Circuit

Schematic

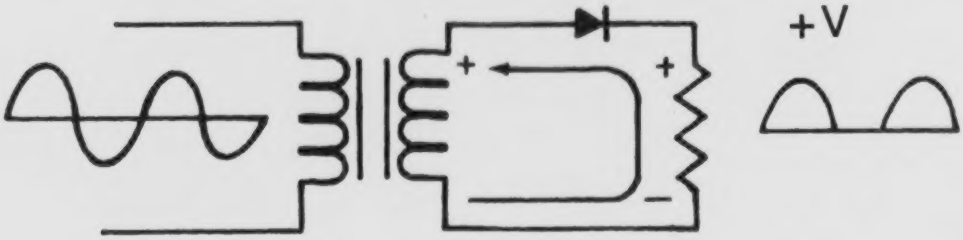
Half-Wave Rectifier Circuits

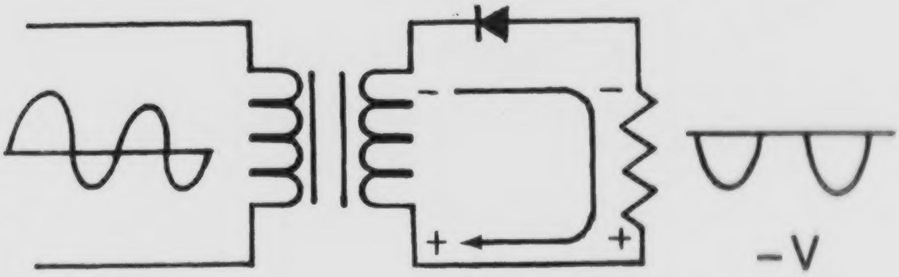

+
– Input Voltage
Load Resistor
+
Output Voltage –


+
– Input Voltage
Load Resistor
+
–
Output Voltage

TM 2

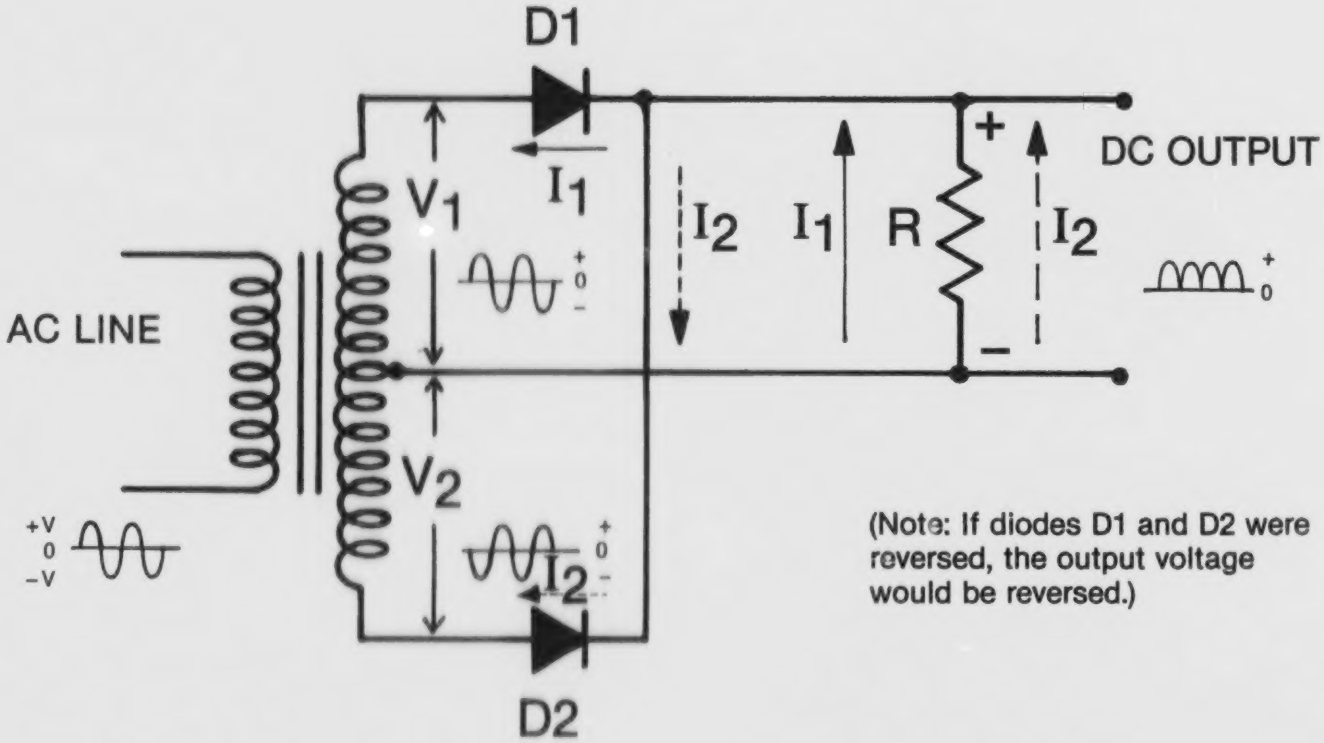
Half-Wave Rectifier Output





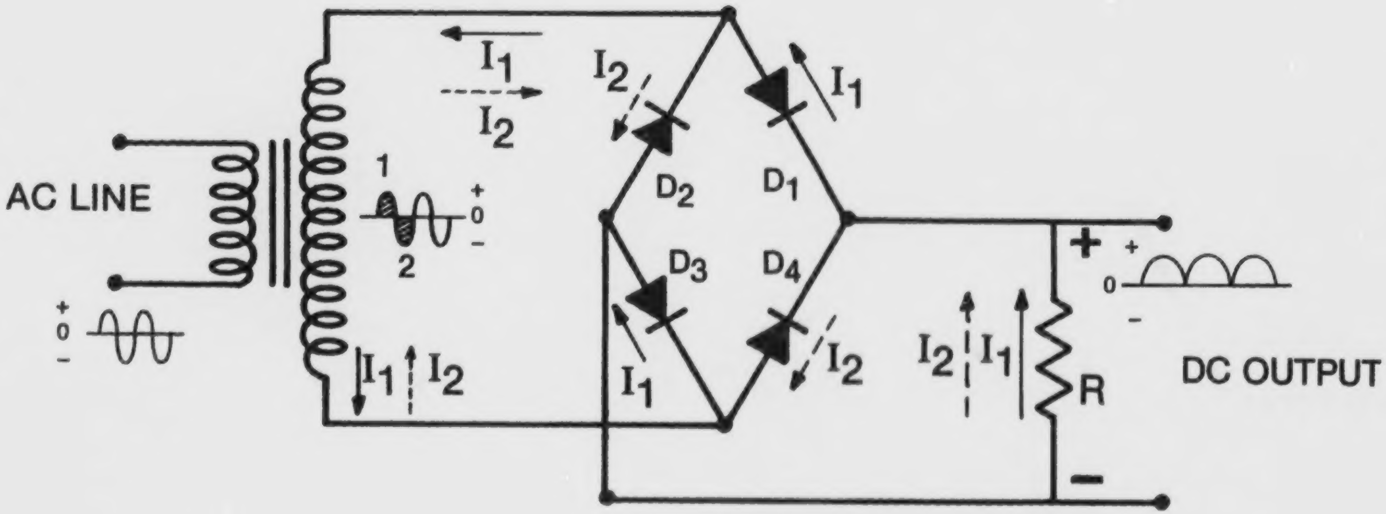
TM 3

Conventional Full-Wave Rectifier


D1
I_1
V_1
+
0
–
AC LINE
+V
0
–V
V_2
+
0
–
I_2
D2
I_2
I_1
R
+
–
I_2
DC OUTPUT
+
0

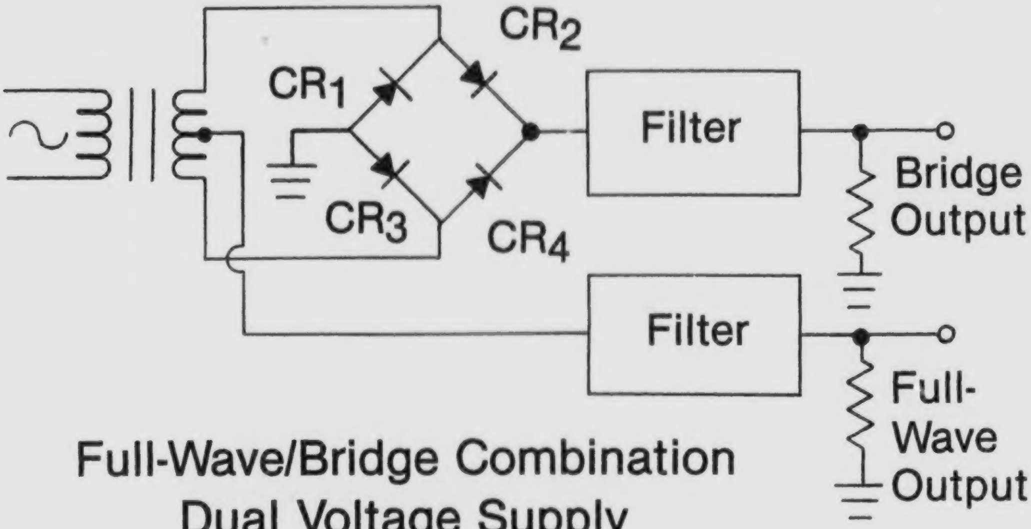
(Note: If diodes D1 and D2 were reversed, the output voltage would be reversed.)

Bridge Rectifier

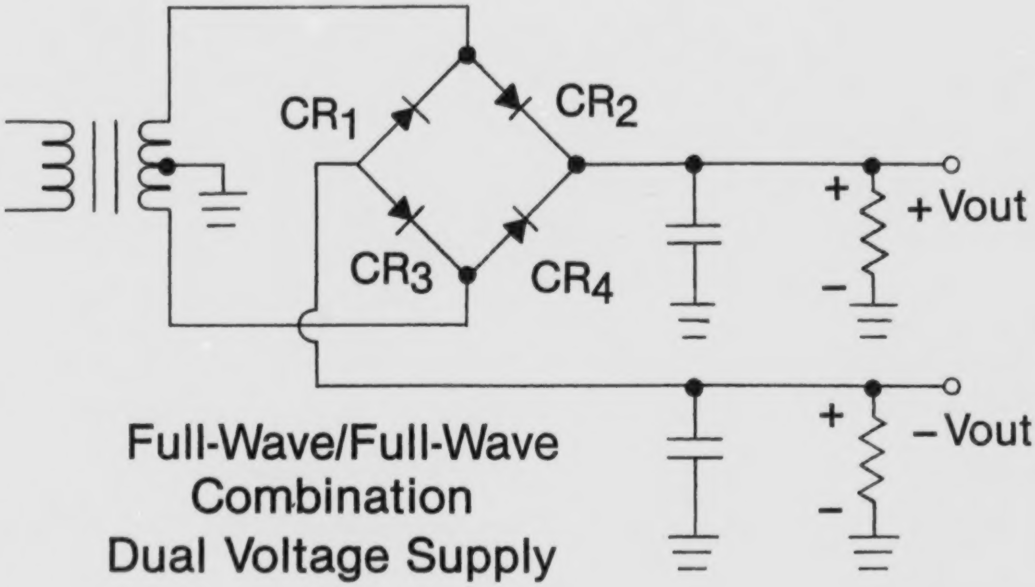

AC LINE
+
0
-
I1
I2
1
2
+
0
-
I1
I2
I2
I1
D2
D1
D3
D4
I1
I2
I2
I1
R
+
-
+
0
-
DC OUTPUT

(Note: If each of the diodes were reversed the output would be reversed.)

Combination Power Supplies

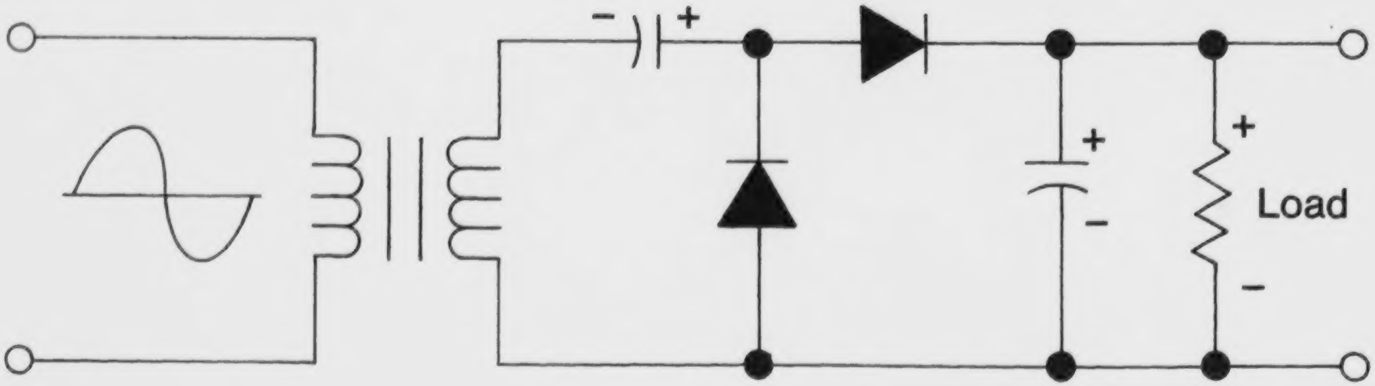

CR1
CR2
CR3
CR4
Filter
Filter
Bridge Output
Full-Wave Output

Full-Wave/Bridge Combination
Dual Voltage Supply

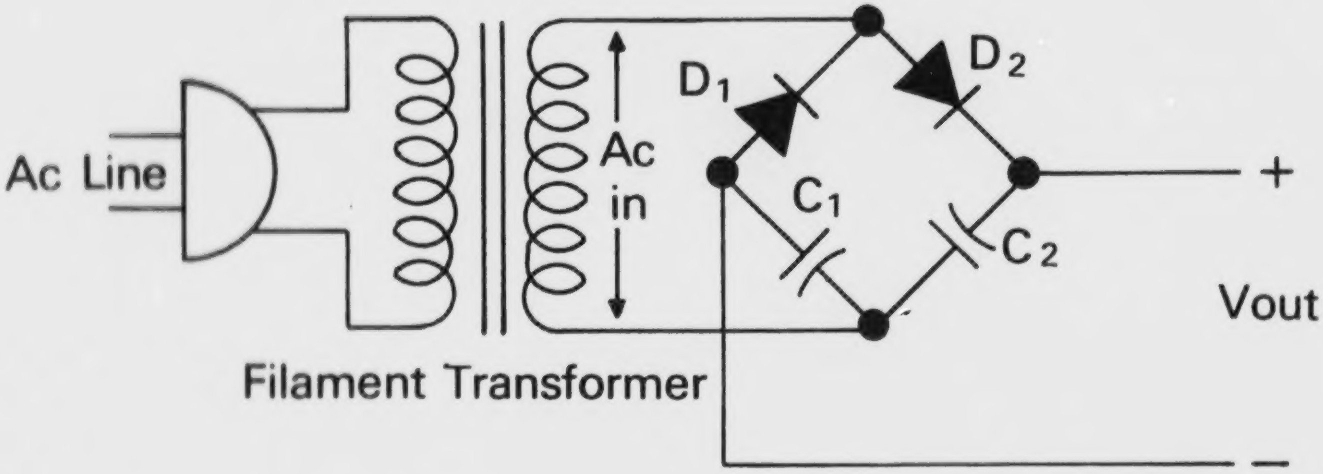

CR1
CR2
CR3
CR4
+
−
+Vout
+
−
−Vout

Full-Wave/Full-Wave
Combination
Dual Voltage Supply

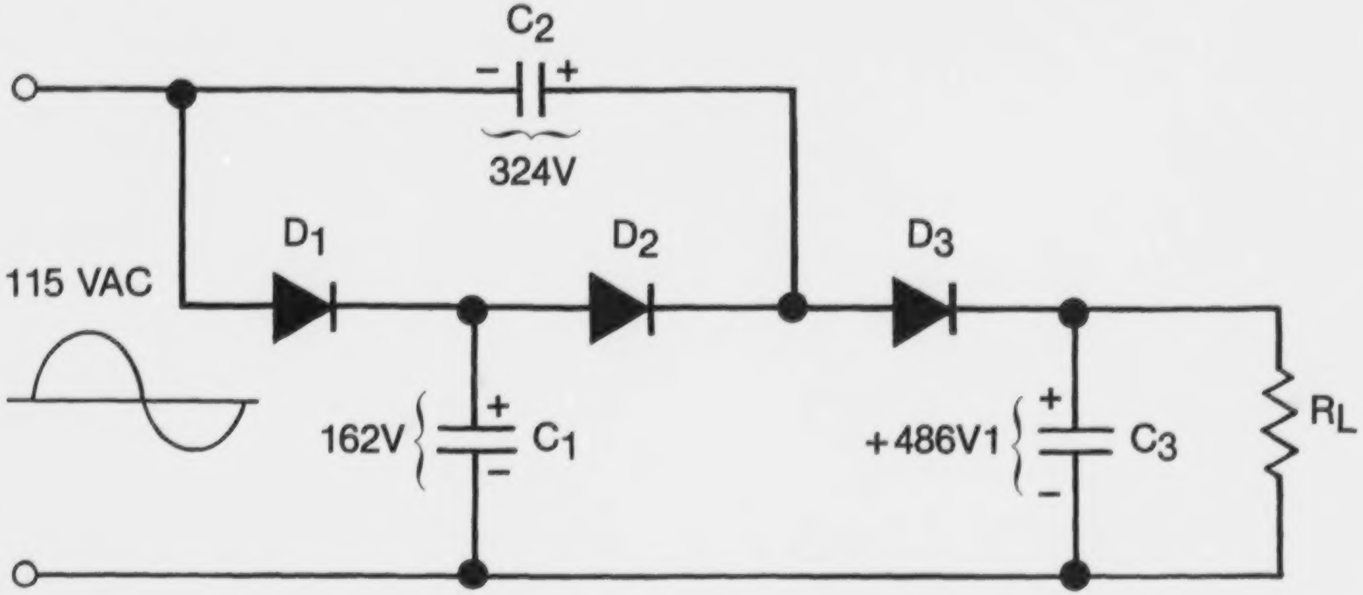
Half-Wave Voltage Doubler Circuit



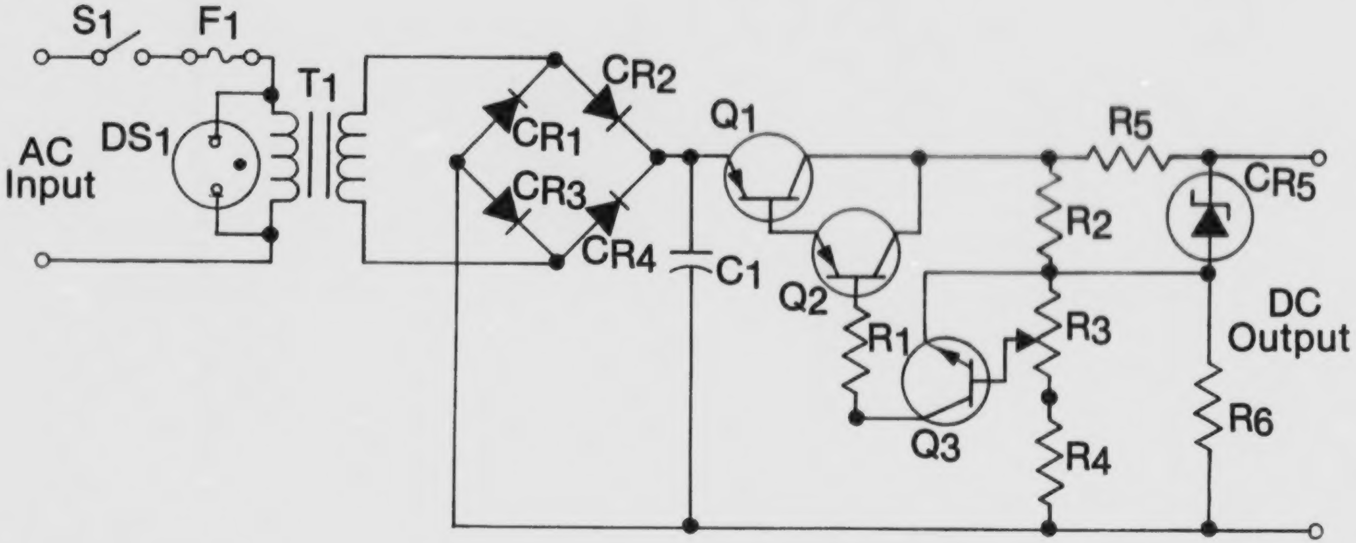
Full-Wave Voltage Doubler Circuit


Ac Line
Ac in
D1
D2
C1
C2
+
−
Vout
Filament Transformer

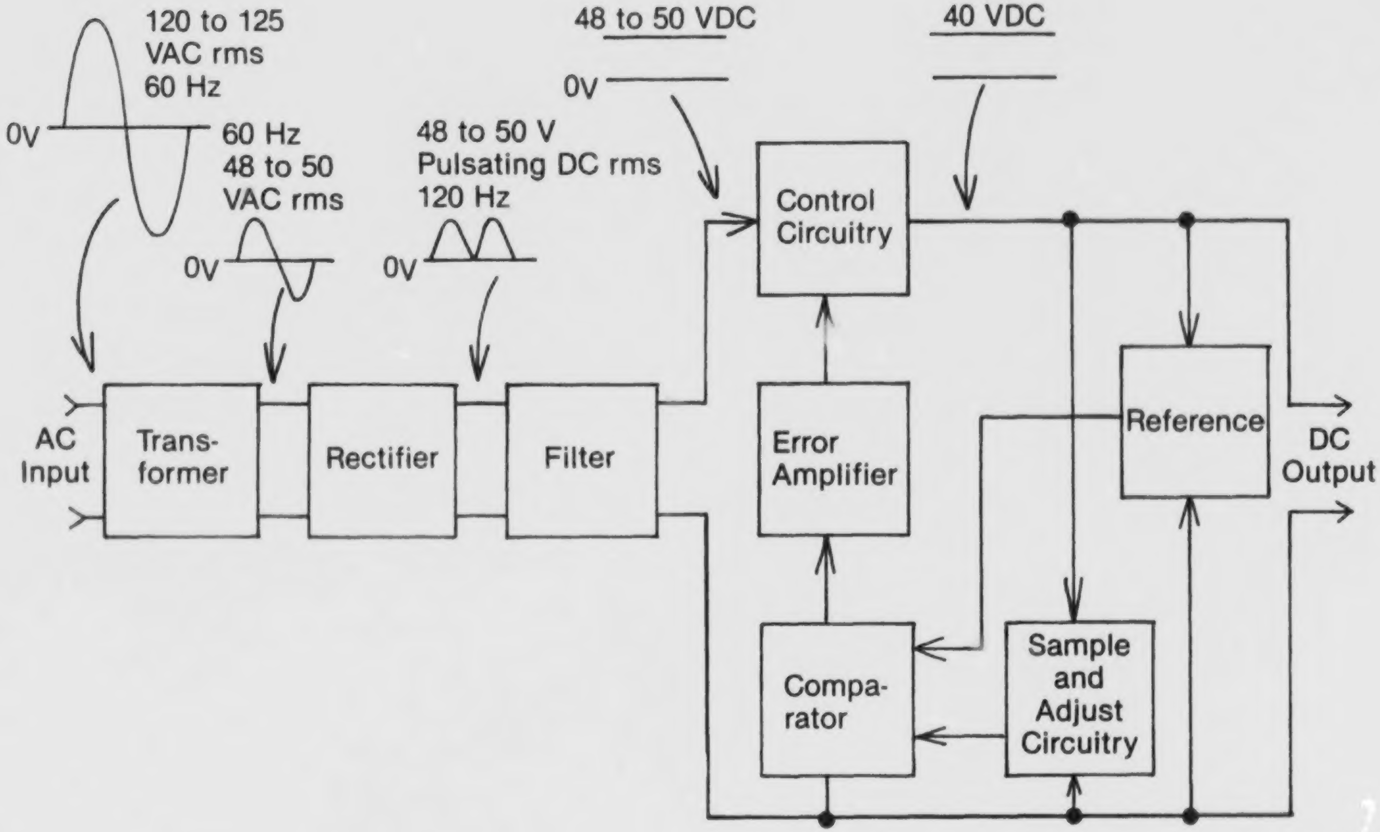
Voltage Tripler


C2
−
+
324V
D1
D2
D3
115 VAC
162V
+
−
C1
+486V1
+
−
C3
RL

Simple Regulated Power Supply


S1
F1
T1
AC
Input
DS1
CR2
CR1
CR3
CR4
C1
Q1
Q2
R1
Q3
R5
R2
R3
R4
CR5
DC
Output
R6

Regulated Power Supply Block Diagram

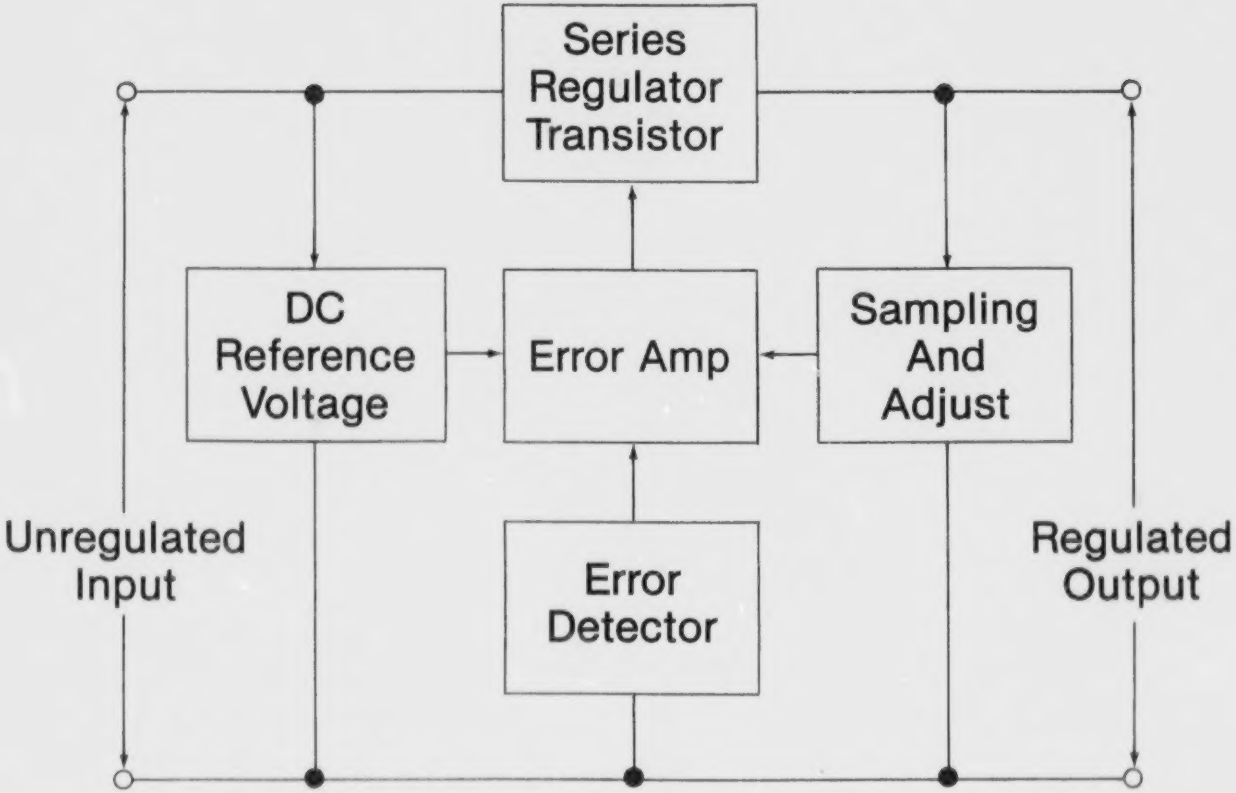


120 to 125
VAC rms
60 Hz
0V
60 Hz
48 to 50
VAC rms
0V
48 to 50 V
Pulsating DC rms
120 Hz
0V
48 to 50 VDC
0V
40 VDC
AC
Input
Trans-
former
Rectifier
Filter
Control
Circuitry
Error
Amplifier
Compa-
rator
Sample
and
Adjust
Circuitry
Reference
DC
Output

General Electronics Technician: Semiconductor Devices and Circuits, Unit 3
Teacher Page 43

TM 11

Feedback Regulator



Series Regulator Transistor

DC Reference Voltage

Error Amp

Sampling And Adjust

Error Detector

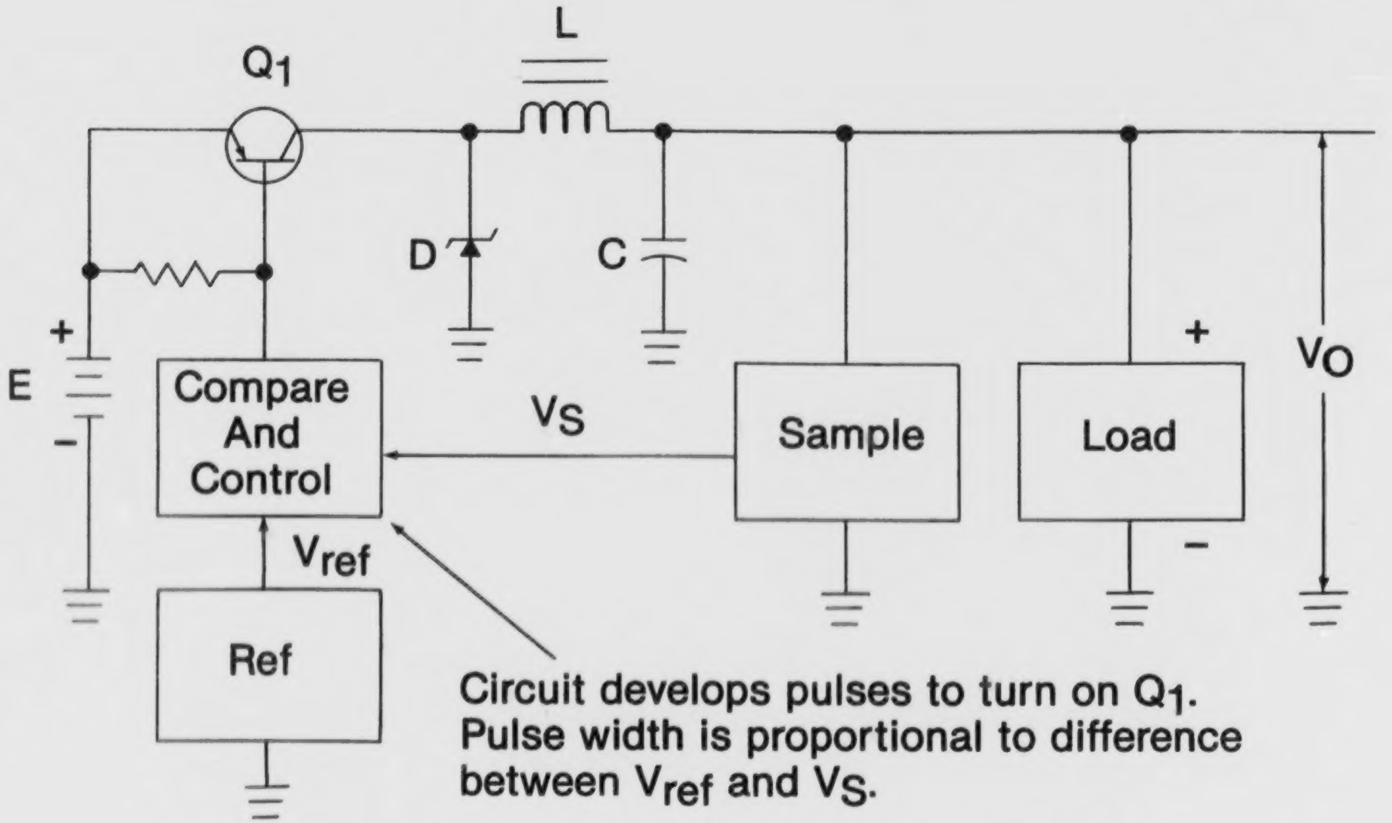
Unregulated Input

Regulated Output

General Electronics Technician: *Semiconductor Devices and Circuits*, Unit 3
Teacher Page 45

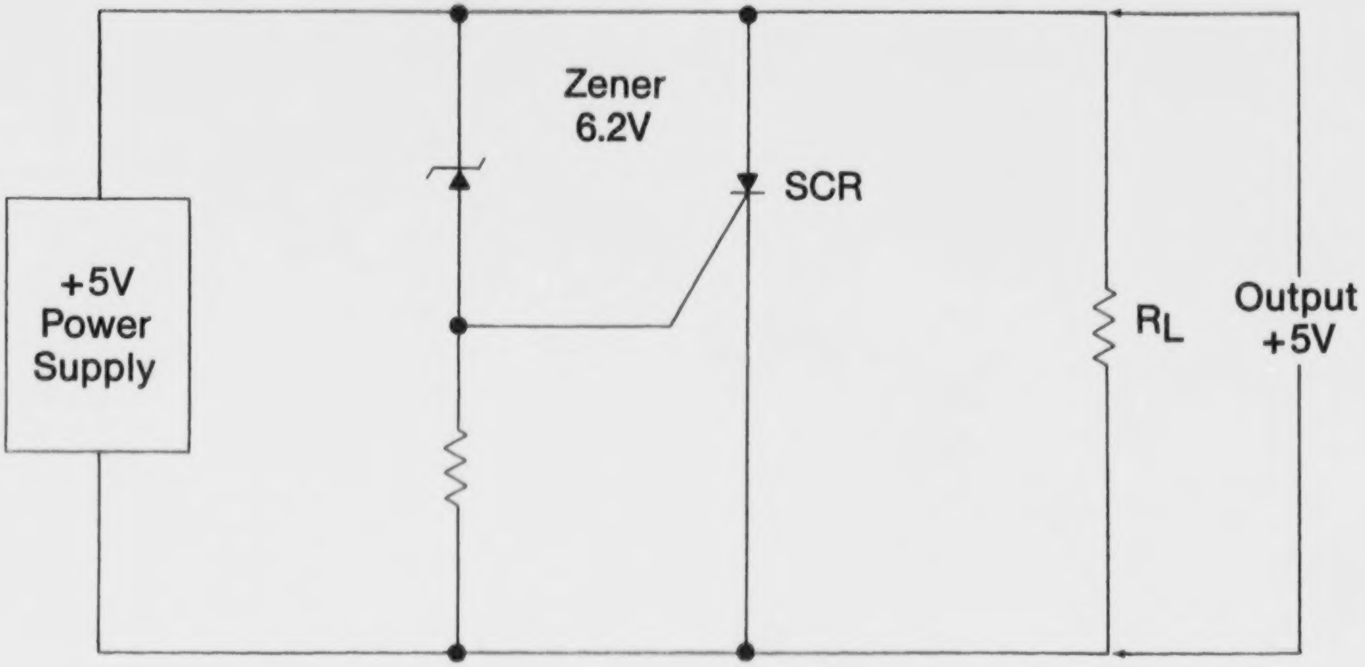
TM 12

Switching Regulator


Q1
L
D
C
+
E
–
Compare And Control
VS
Sample
Load
+
–
VO
Vref
Ref

Circuit develops pulses to turn on Q_1. Pulse width is proportional to difference between V_{ref} and V_S.

Load Protection


Zener
6.2V
SCR
+5V
Power
Supply
R_L
Output
+5V

"Crowbar" Protection Circuit

General Electronics Technician: Semiconductor Devices and Circuits

Student Edition

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General Electronics Technician:

Semiconductor Devices and Circuits

Student Edition

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General Electronics Technician:

Semiconductor Devices and Circuits

Student Edition

Table of Contents

SC

Unit 1: Discrete Semiconductor Devices and Circuits 1

Unit 2: Linear Integrated Devices and Circuits 163

Unit 3: Power Supplies 241

Discrete Semiconductor Devices and Circuits
Unit 1

Objective Sheet

Unit Objective

After completing this unit, the student should be able to discuss semiconductor devices and circuits and construct and test basic semiconductor circuits. The student should demonstrate these competencies by completing the assignment sheets and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms associated with semiconductor devices and circuits to their correct definitions.
2. List circuit applications of common discrete semiconductor devices.
3. Distinguish between forward and reverse biasing.
4. Complete statements regarding the characteristics of semiconductor materials in constructing electronic devices.
5. Distinguish between electrical flow in P- and N-type materials.
6. Complete statements regarding the characteristics of the P-N junction.
7. Complete statements regarding diode operation.
8. Match types of discrete semiconductor diodes to their correct descriptions.
9. List uses of discrete semiconductor diodes.
10. Match discrete semiconductor diodes to their correct symbols.
11. List reasons for diode failure.
12. Identify transistors by their structures and their electrical equivalents.
13. Match types of transistors to their correct descriptions.
14. Match types of transistors to their correct symbols.
15. Complete statements regarding the characteristics of bipolar transistors.

Objective Sheet

16. Describe the operation of an NPN transistor.
17. Describe the operation of a PNP transistor.
18. Distinguish among characteristics of transistor emitters, bases, and collectors.
19. Complete statements regarding the common-base circuit.
20. Complete statements regarding the common-collector circuit.
21. Complete statements regarding the common-emitter circuit.
22. State the purpose of biasing in bipolar transistor circuits.
23. Match methods for biasing bipolar transistors to their correct descriptions.
24. Complete statements regarding field effect transistors.
25. Complete statements regarding the common-gate circuit.
26. Complete statements regarding the common-drain circuit.
27. Complete statements regarding the common-source circuit.
28. State the purpose of biasing in FET circuits.
29. Match methods for biasing FETs to their correct descriptions.
30. Complete statements regarding insulated gate field effect transistors.
31. Select from a list correct handling precautions for IGFETs.
32. List characteristics of an ideal amplifier.
33. Select from a list ways of classifying amplifiers.
34. Describe the operation of a single-stage amplifier circuit.
35. Complete statements regarding the characteristics of power amplifiers.
36. Identify transistor configurations of power amplifiers.
37. Describe amplifier operating conditions.
38. Match methods of coupling transistor amplifier circuits to their correct descriptions.
39. Identify classes of transistor amplifier circuits by characteristics of the circuit.

Objective Sheet

40. Arrange in order the steps for troubleshooting transistor amplifier circuits.

41. Complete statements regarding the operation of a unijunction transistor.

42. State the purpose of each section of an oscillator circuit.

43. Match common oscillator configurations to their correct descriptions.

44. Match thyristors to their correct descriptions.

45. Identify thyristors by their symbols and their electrical equivalents.

46. Identify rectified waveforms.

47. Match rectifier circuits to their correct schematics.

48. Identify types of voltage regulators by their schematics.

49. Use resource materials to determine pin configurations for common types of semiconductor devices. (Assignment Sheet 1)

50. Interpret functions of electronic circuits constructed from discrete semiconductor components. (Assignment Sheet 2)

51. Label the parts of a transistor circuit. (Assignment Sheet 3)

52. Construct a load line for a common-emitter amplifier circuit. (Assignment Sheet 4)

53. Calculate the gain of amplifier circuits. (Assignment Sheet 5)

54. Compute voltage, current, and power stage gain in decibels. (Assignment Sheet 6)

55. Calculate the overall gain of multistage amplifiers. (Assignment Sheet 7)

56. Identify types of transistors used in oscillators. (Assignment Sheet 8)

57. Perform a static test of semiconductor diodes. (Job Sheet 1)

58. Test a semiconductor diode and plot characteristic curves. (Job Sheet 2)

59. Construct and test a half-wave rectifier circuit. (Job Sheet 3)

60. Construct and test a full-wave bridge rectifier circuit. (Job Sheet 4)

61. Test and replace light-sensitive devices. (Job Sheet 5)

62. Test transistors. (Job Sheet 6)

Objective Sheet

63. Construct and test a common-emitter circuit. (Job Sheet 7)

64. Construct and test a common-base circuit. (Job Sheet 8)

65. Construct and test a common-collector circuit. (Job Sheet 9)

66. Plot a transistor output characteristic curve. (Job Sheet 10)

67. Construct and test a single-ended amplifier. (Job Sheet 11)

68. Construct and test a push-pull amplifier. (Job Sheet 12)

69. Construct and test a two-stage, direct-coupled amplifier. (Job Sheet 13)

70. Construct and test a Darlington pair amplifier. (Job Sheet 14)

71. Construct and test a Hartley oscillator. (Job Sheet 15)

72. Test and replace silicon-controlled rectifiers. (Job Sheet 16)

73. Troubleshoot discrete solid-state device circuits. (Job Sheet 17)

Discrete Semiconductor Devices and Circuits
Unit 1

Information Sheet

1. **Terms and definitions**

   a. **Acceptor**—An impurity added to a semiconductor to create P-type material that is rich in holes that accept electrons

   b. **Ambient temperature**—Air temperature around a device or circuit

   c. **Anode**—Positive electrode of an electrical or electronic device

   d. **Breakdown voltage**—Amount of reverse-biased voltage required to suddenly increase reverse current flow

   e. **Cathode**—Negative electrode of an electrical or electronic device

   f. **Clipping**—Signal distortion characterized by loss of amplitude usually as a result of improper biasing or excessive input signal strength

   g. **Depletion**—Condition of a semiconductor crystal having few available current carriers

   Note: An area of depletion called the depletion region is normal in most operating semiconductors in the boundary between P-type material and N-type material where the active exchange of holes and electrons occurs.

   h. **Donor**— An impurity added to a semiconductor to create N-type material that is rich in electrons that can be donated to other atoms

   i. **Doping**—Process of adding impurities to semiconductor material crystals in order to change their electrical properties

   j. **Electrical equivalent**—Circuit that consists of one set of components that is electrically identical to a circuit composed of a different set of components

   k. **Junction**—Area of contact in a semiconductor between P-type material and N-type material

   l. **Majority carrier**—In a semiconductor material, the current carrier that is present in the greater quantity

   Note: In P-type material (positive), excess holes are more prominent than excess electrons and are the majority carrier. In N-type material (negative), there are more excess electrons than holes, making electrons the majority carrier. Also see *minority carrier*.

m. **Minority carrier**—In a semiconductor material, the current carrier that is present in the lesser quantity

n. **N-type material**—Semiconductor material that has been doped with a donor impurity so that it conducts current with electrons

o. **Optoelectronic device**—Component capable of producing an electric current when exposed to light or producing light electronically when power is applied

Examples: Light-emitting diode, phototransistor

p. **P-type material**—Semiconductor material that has been doped with an acceptor impurity so that it conducts current with holes

q. **Rectification**—Process of changing AC to DC

r. **Semiconductor**—Substance whose electrical characteristics with regard to current flow lie between those of conductors and insulators

Note: Circuits and equipment that use semiconductors are sometimes referred to as *solid-state* because mechanical switches and connections have largely been replaced by solid material devices.

s. **Surge**—Sudden increase in current or voltage

2. Common discrete semiconductor devices and their circuit applications

a. Diodes

- Rectifiers
- Voltage regulators
- Signal blocking

b. Bipolar transistors

- Amplifiers
- Oscillators
- Switches

c. Field-effect transistors

- Amplifiers

Information Sheet

  - Oscillators
  - Switches

d. Unijunction transistors

  - Timers
  - Oscillators
  - Triggers

e. Thyristors

  - Switches
  - Triggers
  - Oscillators

3. Forward and reverse biasing

Note: *Biasing* is the act of applying current to an electronic device.

a. When the current causes the device to promote electrical flow (be *on*), it is called *forward biasing*.

b. When the current causes the device to oppose electrical flow (be *off*), it is called *reverse biasing*.

4. Characteristics of semiconductor materials in constructing electronic devices

a. The conductivity of a semiconductor material can be increased significantly by adding an impurity to the semiconductor through a process called *doping*.

b. When a semiconductor is doped with an element containing five valence electrons, called a *pentavalent* element, it becomes N-type material.

Examples: Silicon or germanium doped with arsenic

c. When a semiconductor is doped with an element containing three valence electrons, called a *trivalent* element, it becomes P-type material.

Example: Silicon or germanium doped with boron

d. The majority of current in N-type materials is carried by the electrons.

Information Sheet

e. The majority of current in P-type materials is carried by the holes.

f. Impurity atoms in N-type materials are called *donor atoms*.

g. Impurity atoms in P-type materials are called *acceptor atoms*.

5. **Difference between electrical flow in P- and N-type materials**

a. When voltage is applied to an N-type material, the electrons move from the negative terminal toward the positive terminal of the voltage source

b. When voltage is applied to a P-type material, the holes flow from the positive terminal toward the negative terminal of the voltage source

6. **Characteristics of the P-N junction**

a. The structure of semiconductor materials is referred to as *crystals*.

b. Through various manufacturing methods, semiconductor crystals can be formed so that one portion is P-type material and the other portion is N-type material.

c. The area between the two types of material is call the *P-N junction* or *depletion region*.

Note: When the P-N crystal is being manufactured, some free electrons move across from the N-side to fill holes in the P-side. As a result, there are no free carriers, and they are said to be depleted. This transfer of electrons continues until the material reaches an electrical potential that varies based on the element being doped, temperature, and other factors.

d. The resulting semiconductor device is referred to as a *P-N junction diode* or simply *junction diode* because it allows current flow in one direction while blocking it in the other direction.

Note: *Diode* refers to the fact that the semiconductor material has two poles or terminals, a cathode and an anode. While this structure is used as a discrete device that is called a diode, the same structure forms the basis for many other semiconductor devices that will be covered in this unit.

e. Because the junction has no free electrons or holes, it acts as an insulator or *barrier*.

f. The junction region will continue to act as a barrier until the applied voltage exceeds the *barrier potential*.

Note: The depletion region shrinks when forward biasing current is applied and grows during reverse biasing. But the junction will continue to be a barrier even

Information Sheet

with forward biasing until the voltage is high enough to overcome the initial resistance. This voltage level is referred to as *barrier potential*. The barrier potential for silicon semiconductors is approximately 0.6 to 0.7 volts, while the barrier potential for germanium semiconductors is approximately 0.2 to 0.3 volts.

g. In a junction diode, forward biasing results when the negative terminal of the voltage source is attached to the N-type material side of the diode and the positive terminal of the voltage source is attached to the P-type material side of the diode and the voltage is raised beyond the barrier potential.

h. In a junction diode, reverse biasing results when the negative terminal of the voltage source is attached to the P-type material side of the diode and the positive terminal of the voltage source is attached to the N-type material side of the diode and the voltage is raised beyond the barrier potential.

i. Some amount of current flow results even with reverse biasing and is referred to as *leakage current*.

Note: Leakage current tends to be higher in germanium semiconductors than silicon semiconductors. Modern doping processes can lower the leakage current in silicon diodes to a level that is not measurable with ordinary meters.

7. Diode operation

a. The basic diode structure is a two-lead device with an *anode* formed by the P-type material section of the diode and a *cathode* formed by the N-type material section of the diode.

b. Normal current flow through the diode goes from the cathode to the anode.

c. When current is applied to a diode through forward biasing, there is virtually no flow until the barrier potential is reached.

d. Once past the barrier potential, forward current increases rapidly in a fairly linear fashion.

e. If the forward voltage continues to increase, the diode will be damaged at a characteristic value referred to as *maximum current* (I_f).

f. When current is applied to a diode through reverse biasing, there is virtually no flow.

g. At a voltage level referred to as *breakdown* voltage, there is a rapid increase in the reverse current through minority carriers.

h. If the reverse voltage continues to increase, the diode will be damaged at a characteristic value referred to as *peak inverse voltage (PIV)*.

8. Types of discrete semiconductor diodes

a. Diode—Two-terminal device that allows current flow in one direction only

b. Zener (avalanche) diode—Diode designed to operate at a specific value of reverse breakover with a very stable voltage drop

c. Tunnel diode—Diode with a narrow depletion region and a high barrier voltage

d. Backward diode (back diode)—Diode with characteristics similar to a conventional diode except that it produces a very low forward voltage drop

e. Photodiode—Diode that produces current proportional to the power level of light that strikes it

f. PIN diode—Diode that has a wide depletion region capable of making very fast changes of operating states

Note: PIN stands for *P-Intrinsic-N*, referring to its composition of a P-doped region and N-doped region with a natural or intrinsic undoped region between.

g. Light-emitting diode (LED)—Diode, usually made of gallium semiconductor, that gives off light when forward biased

h. Schottky (hot carrier) diode—Diode constructed with N-type material and a metal anode deposited on the semiconductor material

i. IMPATT (impact avalanche transit time) diode—Diode that operates in its reverse breakdown region that is capable of generating radio frequency power

j. Varactor (varicap) diode—Diode that operates like a variable capacitor with its two semiconductor regions serving as the capacitor plates and the depletion region serving as a variable space between them

k. Varistor—Device capable of withstanding heavy currents for short periods of time that behaves like a diode because of the alignment of metal (often zinc) oxide grains within its material

l. Thyrector (bidirectional diode)—Device that provides AC flow in either direction while still blocking DC

9. Uses of discrete semiconductor diodes

a. Diode—Rectification, blocking, detecting, steering

b. Zener (avalanche) diode—Regulation, reference, clipping

c. Tunnel diode—UHF converter, logic circuits, microwave circuits, level sensing

Information Sheet

d. Backward diode—Microwave mixers, low-power oscillators

e. Photodiode—Fiber optic circuits, light sensors

f. PIN diode—Variable resistor, microwave circuits

g. Light-emitting diode—Indicators, displays

h. Schottky (hot carrier) diode—Switching, RF mixer, harmonic generation

i. IMPATT (impact avalanche transit time) diode—RF power generator, microwave circuits

j. Varactor (varicap) diode—Amplifiers, oscillators, voltage multipliers

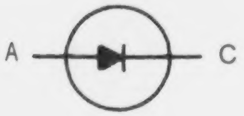
k. Varistor—Voltage divider, surge suppresser

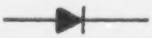
l. Thyrector (bidirectional diode)—Transient voltage suppression

10. Symbols for discrete semiconductor diodes

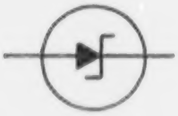
a. Diode

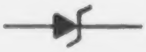
Note: The symbols below show the two most common ways of representing the basic diode. The symbol may be shown with or without a circle and the arrowhead portion of the symbol may or may not be shown solid. None of those variations has a real significance in common practice. The most consistent standard for the symbol is that the arrowhead points toward the cathode. This symbol then becomes the basis for many of the symbols for the various types of diodes, rectifiers, and control devices.



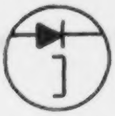


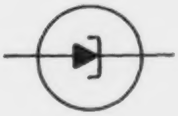
b. Zener (avalanche) diode



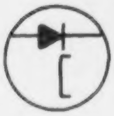


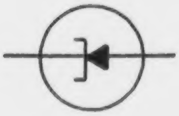
c. Tunnel diode



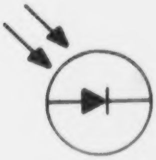


d. Backward diode



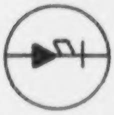


e. Photodiode

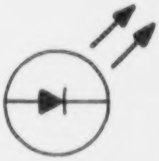


f. PIN diode

Note: Unless it is necessary to show the intrinsic region, a conventional diode symbol is often used to show a PIN diode.

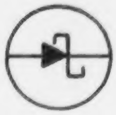


g. Light-emitting diode



Information Sheet

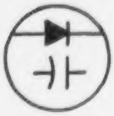
h. Schottky (hot carrier) diode

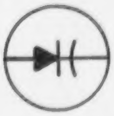


i. IMPATT (impact avalanche transit time) diode

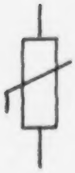
Note: A conventional diode symbol is normally used for the IMPATT diode.

j. Varactor (varicap) diode

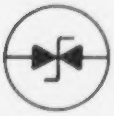




k. Varistor



l. Thyrector (bidirectional diode)



11. Reasons for diode failure

a. Heat

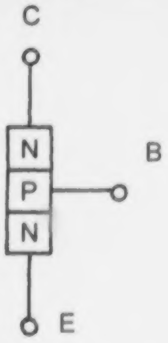
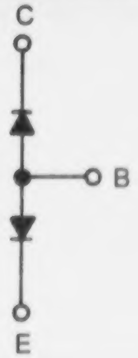
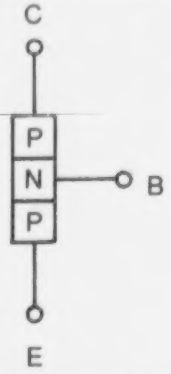
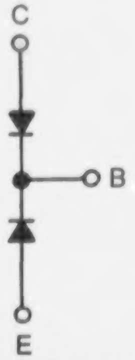
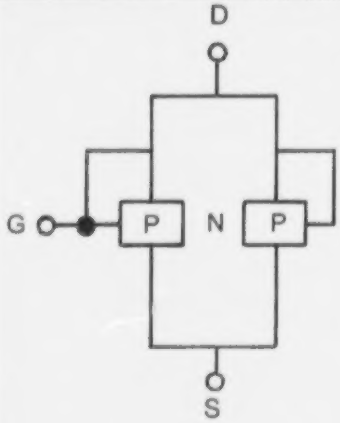
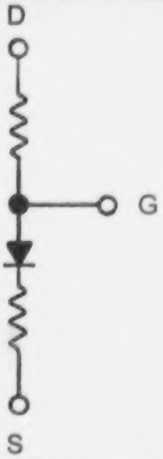
b. Shock

Note: Shock may be electrical, such as ESD damage; physical, such as rough handling; or thermal, as in a case where the ambient temperature around the diode changes quickly from very hot to very cold or from very cold to very hot. Most semiconductor devices are susceptible to heat, shock, damage from excessive current to some degree.

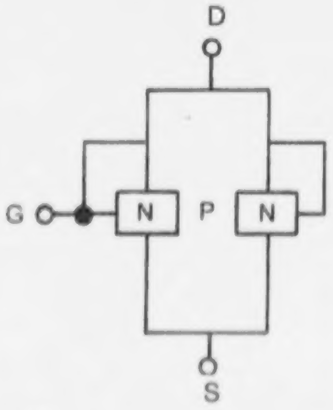
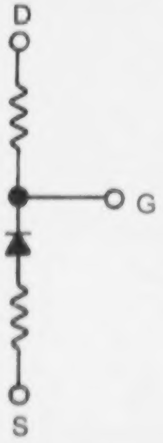
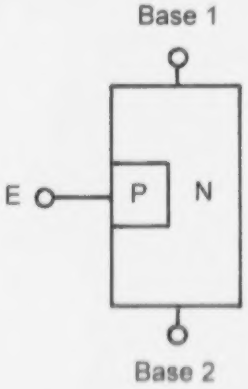
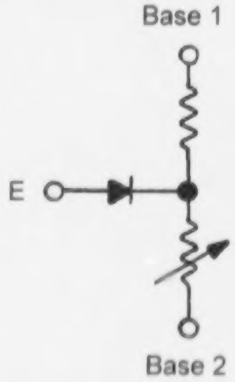
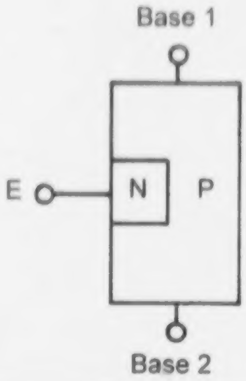
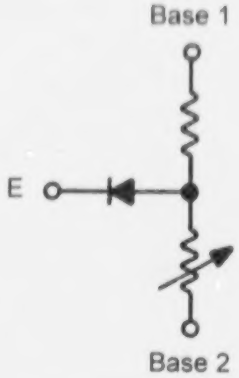
c. Excessive current

Information Sheet

12. Basic structures of transistors and their electrical equivalents

Transistor	Structure	Electrical Equivalent
Bipolar junction transistor (BJT)		
- NPN		
- PNP		
Field-effect transistor (FET)		
- N-channel		

Information Sheet

Transistor	Structure	Electrical Equivalent
- P-channel		
Unijunction transistor (UJT)		
- N-type base	 Base 1 E P N Base 2	 Base 1 E Base 2
- P-type base	 Base 1 E N P Base 2	 Base 1 E Base 2

Information Sheet

13. Types of transistors

a. NPN transistor—Transistor with an emitter consisting of N-type material, a base of P-type material, and a collector of N-type material

b. PNP transistor—Transistor with an emitter consisting of P-type material, a base of N-type material, and a collector of P-type material

c. Phototransistor—Transistor designed to use light as a control source

Note: All transistors react to light, but most have sealed cases to prevent the semiconductor material from being exposed to light. In phototransistor cases, a window allows light in to turn on the device. In some designs, light is used in place of base current so the transistor has only collector and emitter leads.

d. Field-effect transistor (FET) or junction field-effect transistor (JFET)—Transistor that uses gate voltage to control the resistance of an internal channel and that operates in the depletion mode

e. Dual-gate JFET—FET that has two external leads for gates

f. Metal oxide semiconductor field-effect transistor (MOSFET)—FET in which the gate is electrically isolated from the source-drain channel

g. Complementary metal oxide semiconductor field-effect transistor (C-MOSFET) circuit—Circuit configuration using one P-channel MOSFET and one N-channel MOSFET with a shared gate terminal

h. Enhanced-mode MOSFET—MOSFET that is off when the bias voltage is zero

i. Depletion-mode MOSFET—MOSFET that is on when the bias voltage is zero

j. Vertical metal oxide semiconductor field-effect transistor (VMOSFET or VFET)—Enhanced-mode MOSFET in which the source and drain are located on opposite sides of the substrate layers from each other

Note: Technological developments have spawned many variations in MOS construction suitable for power circuits due to their ability to handle relatively large currents. They often use similar names, such as double-diffused MOS (DMOS), T-MOS, and power C-MOS.

k. Insulated gate bipolar transistor—An enhancement-mode device with vertical structure and a FET-type gate rather than a base lead

l. Unijunction transistor (UJT)—N-type material body with small region of P-type material that does not penetrate the N-type material completely, resulting in a device that switches on quickly when its standoff voltage is reached

Note: In many ways, UJTs are more like thyristors than transistors. While many transistors are used as amplifiers, UJTs serve primarily as switching devices.

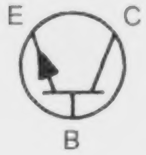
Information Sheet

m. Complementary unijunction transistor (CUJT)—A unijunction transistor with a P-type material body and a small region of N-type material

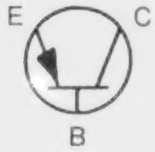
n. Programmable unijunction transistor (PUT)—Unijunction transistor that is gated with two internal resistors

14. Transistor symbols

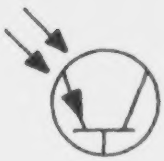
a. NPN transistor



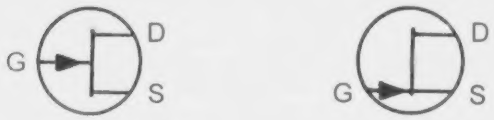
b. PNP transistor



c. Phototransistor (PNP-type shown)

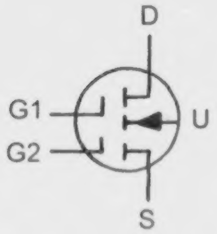


d. Field-effect transistor (N-channel type shown)



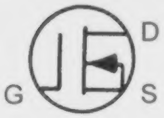
Information Sheet

e. Dual-gate JFET

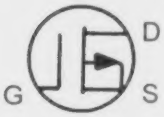


f. Insulated-gate field-effect transistor (N-channel, depletion-mode shown)

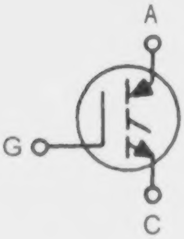
Note: The IGFETs illustrated (items *f* and *g*) are both single-gate, internally terminated substrate configurations that have three external leads. Some IGFETs are built with an external termination of the substrate and have four leads. An IGFET may also be dual-gated, meaning that it could have up to five leads. No distinction is made in the symbol to indicate MOS, V-MOS, C-MOS, or T-MOS compositions.



g. Insulated-gate field-effect transistor (P-channel, depletion-mode shown)

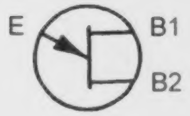


h. Insulated gate bipolar transistor

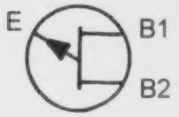


Information Sheet

i. Unijunction transistor

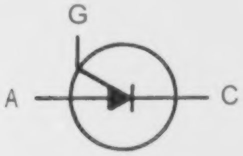


j. Complementary unijunction transistor



k. Programmable unijunction transistor

Note: The PUT symbol is the same as the complementary SCR symbol.



15. Characteristics of a bipolar transistor

a. The basic bipolar transistor package has three leads referred to as *emitter*, *collector*, and *base*.

b. The transistor body consists of three sections of semiconductor material, put together as NPN or PNP.

c. The sandwiched material is the base.

d. The emitter section is heavily doped and contains a higher percentage of majority carriers, which move through the base and into the collector.

e. These devices are often called *bipolar junction* transistors because they contain two P-N junctions and both electrons and holes are available as carriers.

f. The junctions are referred to as the *collector-base junction* and the *base-emitter junction*.

g. Bipolar transistors are controlled by current and are normally off.

Information Sheet

h. Current through the collector-base junction is reverse-biased, while current through the base-emitter junction is forward-biased.

i. Resistance in the collector-base junction is relatively high, while resistance in the base-emitter junction is relatively low.

j. The current through the emitter is equal to the sum of the current through the base and the current through the collector; thus, $I_E = I_B + I_C$.

k. One of the characteristics of a transistor that may be cited in specifications is the ratio between the collector current and the emitter current, which is termed with the Greek letter alpha (α) or α_{DC} and is represented by the formula

$$\alpha = \frac{I_C}{I_E}$$

l. The ratio between the base current and collector current is another important characteristic of transistors and is termed with the Greek letter beta (β), β_{DC}, or h_{FE} as represented by the formula

$$\beta = \frac{I_C}{I_B}$$

m. Transistor circuits are generally arranged in one of three basic configurations referred to as common-base (CB), common-emitter (CE), and common-collector (CC).

n. Transistors are packaged in several styles of cases.

16. Operation of an NPN transistor

a. Free electrons flow from the emitter to the base and from the base to the collector.

b. Approximately 5 percent of the electrons come from the emitter, while the rest come from the base.

c. The base is narrow and lightly doped.

17. Operation of a PNP transistor

a. Free electrons flow from the collector to the base and from the base to the emitter.

b. Because the emitter-base region is low resistance, a small input signal results in maximum current flow.

c. The base is narrow and lightly doped.

Information Sheet

18. Characteristics of transistor emitters, bases, and collectors

a. Emitters

- Are most heavily doped section of a transistor
- Have the most majority current carriers
- Carry all current that passes into or out of the transistor
- Are indicated on the transistor symbol by an arrowhead pointing toward the N-type material

b. Bases

- Provide faster frequency response as they become narrower
- Control current flow through the transistor
- Divide the N-type and P-type materials
- Carry only a small portion of the current flowing through the transistor
- Are indicated on the transistor symbol by two perpendicular lines

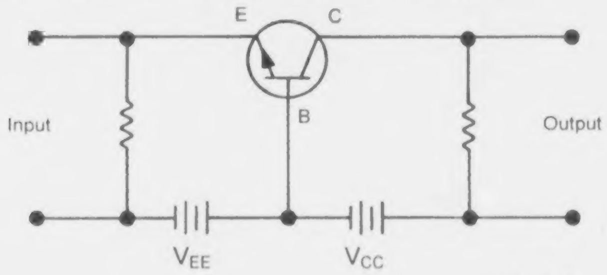
c. Collectors

- Are often connected to the metal case of the transistor
- Carry a large amount of current through the transistor
- Are indicated on the transistor symbol by a diagonal line

19. Characteristics of a common-base circuit

a. The common-base (CB) circuit uses the base of a bipolar transistor as its common reference point and the emitter and collector leads for the input and output.

Example: NPN configuration shown



344

Information Sheet

b. The CB circuit has a relatively high voltage gain.

c. The CB circuit has a low current gain.

d. The CB circuit has a medium power gain.

e. The CB circuit has a low input impedance.

f. The CB circuit has a high output impedance.

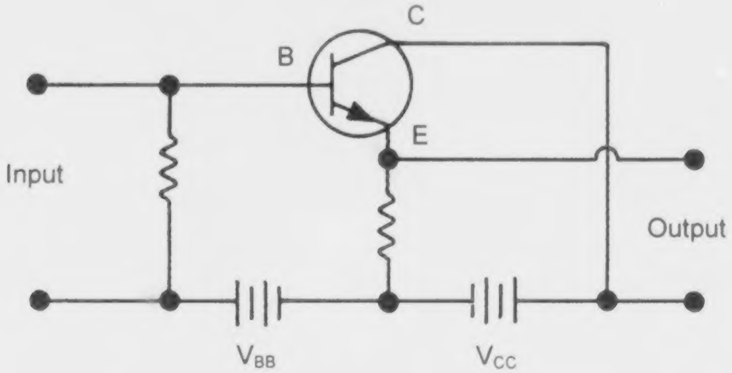
g. The input signal is in-phase with the output signal.

20. Characteristics of a common-collector circuit

a. The common-collector (CC) circuit uses the collector of a bipolar transistor as its common reference point and the emitter and base leads for the input and output.

Note: The CC circuit is also referred to as an *emitter-follower circuit*.

Example: NPN configuration shown



b. The CC circuit has a low voltage gain.

c. The CC circuit has a high current gain.

d. The CC circuit has a low power gain.

e. The CC circuit has a high input impedance.

f. The CC circuit has a low output impedance.

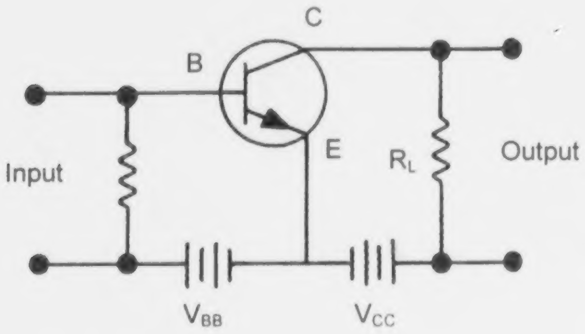
g. The input signal is in-phase with the output signal.

Information Sheet

21. Characteristics of a common-emitter circuit

a. The common-emitter (CE) circuit uses the emitter of a bipolar transistor as its common reference point and the base and collector leads for the input and output.

Example: NPN configuration shown



b. The CE circuit has a relatively high voltage gain.

c. The CE circuit has a high current gain.

d. The CE circuit has a very high power gain.

e. The CE circuit has a medium input impedance.

f. The CE circuit has a medium output impedance.

g. The input signal is out-of-phase with the output signal.

22. **Purpose of biasing bipolar transistor circuits**—To achieve maximum output voltage swing without distortion or to provide a specific output voltage at the collector

Note: Bipolar transistor circuits are usually biased by using resistors with values that produce the proper voltage at the collector, base, and emitter.

23. Methods of bipolar transistor biasing

Note: In practical applications, transistor circuits are generally biased using a single voltage source.

a. Base-biasing—Use of a steady DC voltage applied to the transistor base lead to drive the transistor to its operating point

b. Collector feedback biasing—Use of a resistive feedback circuit connected to the collector so that a drop in collector voltage will lead to rise in feedback voltage to the collector

Note: The feedback circuit provides improved thermal stability, but the circuit is subject to fluctuations due to changes in β.

c. Emitter feedback biasing—Use of a resistive feedback circuit connected between the collector supply voltage and the load resistor

d. Voltage divider biasing (universal biasing)—Use of a four-resistor circuit with resistors across the collector-base junction and the emitter-base junction so that the emitter current remains virtually independent of β

24. Characteristics of field-effect transistors

a. The basic FET package has three leads referred to as *gate*, *source*, and *drain*.

b. The transistor body consists of three sections of semiconductor material, put together as two small areas called *regions* and a larger bulk substrate called the *channel*.

c. The FET is referred to by the material that composes its channel section as either a P-channel or N-channel FET.

d. FETs are controlled by voltage and are normally on.

e. The FET functions essentially as a voltage divider with two resistances consisting of the drain resistance and the channel resistance.

f. Application of a negative voltage (relative to the source) causes the P-N junction to become reverse-biased, leading to a growth in the depletion region.

g. The larger the depletion regions grow, the narrower the channel becomes and the higher the resistance offered by the FET.

h. If the voltage continues to increase, it will eventually reach a point where the reverse bias induced in the depletion regions and the increased resistance in the channel will not allow the current to increase further; this current limiting level is referred to as the FET's *current pinch-off voltage* (V_p).

i. Because the gate-to-source current is essentially shorted at the pinch-off voltage, the current value for the drain-source current is referred to as the *drain-source shorted current* (I_{dss}).

Information Sheet

j. FETs operated with drain-source voltages greater than the pinch-off value are generally used as amplifiers, while those operated with lower drain-source voltages are used as switches.

k. One of the characteristics of a FET that may be cited in specifications is the ratio between the channel current change (ΔI_d) and the gate-to-source voltage change (ΔV_{gs}), which is termed *transconductance* (g_m) or *forward transfer admittance* (Y_{fs}) and is computed with the formula

$$g_m = Y_{fs} = \frac{\Delta I_d}{\Delta V_{gs}}$$

Note: This ratio is only valid once the current has become constant beyond the pinch-off voltage.

l. The gate-to-source voltage required to reduce the drain voltage to zero is called the *gate-to-source cutoff voltage.*

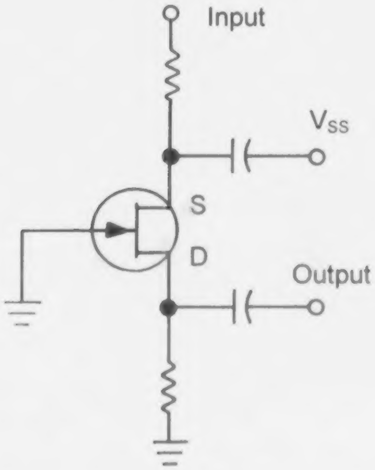
m. FET circuits are generally arranged in one of three basic configurations referred to as common-gate (CG), common-source (CS), and common-drain (CD).

n. FETs are packaged in several styles of cases.

25. Characteristics of a common-gate circuit

a. The common-gate (CG) circuit uses the gate of a FET as its common reference point and the source and drain leads for the input and output.

Example: N-channel configuration shown



b. The CG circuit has a relatively high voltage gain.

c. The CG circuit has a low current gain.

d. The CG circuit has a medium power gain.

e. The CG circuit has a low input impedance.

f. The CG circuit has a high output impedance.

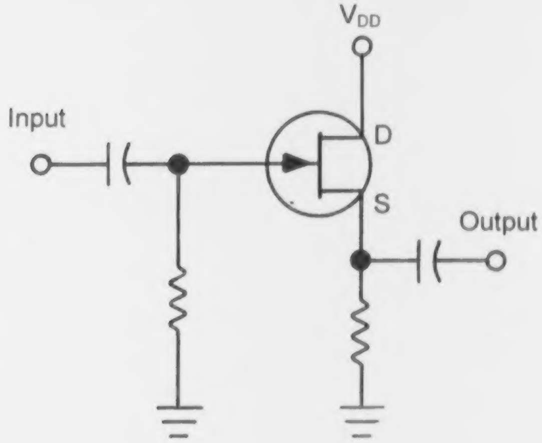
g. The input signal is in-phase with the output signal.

26. Characteristics of a common-drain circuit

a. The common-drain (CD) circuit uses the drain of a FET as its common reference point and the source and gate leads for the input and output.

Note: The CD circuit is also referred to as a *source-follower circuit*.

Example: N-channel configuration shown



b. The CD circuit has a low voltage gain.

c. The CD circuit has a high current gain.

d. The CD circuit has a low power gain.

e. The CD circuit has a high input impedance.

f. The CD circuit has a low output impedance.

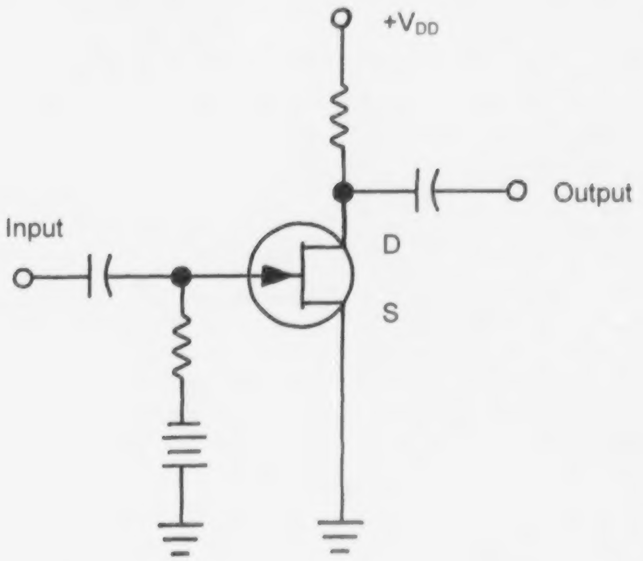
g. The input signal is in-phase with the output signal.

Information Sheet

27. Characteristics of a common-source circuit

a. The common-source (CS) circuit uses the source of a FET as its common reference point and the gate and drain leads for the input and output.

Example: N-channel configuration shown



b. The CS circuit has a relatively high voltage gain.

c. The CS circuit has a high current gain.

d. The CS circuit has a very high power gain.

e. The CS circuit has a high input impedance.

f. The CS circuit has a medium to high output impedance.

g. The input signal is out-of-phase with the output signal.

28. Purpose of biasing FET circuits—To achieve maximum stability in the operating point while preventing operation from going beyond the cutoff

Information Sheet

29. Methods of FET biasing

a. Source biasing—Use of source current flowing through the source resistor to maintain the source terminal positive with respect to ground

Note: This approach is sometimes referred to as *self—biasing*. While this is an acceptable biasing method for JFETs, source biasing of enhancement mode MOSFETs is not possible due to the fact that there is no current flow.

b. Fixed biasing—Use of a separate bias supply across the gate-source junction to maintain the gate current near zero

c. Combination (voltage divider)biasing—Use of a voltage divider to provide a fixed positive voltage to the gate terminal and source bias

30. Characteristics of insulated gate field-effect transistors

a. The basic IGFET package has three leads referred to as *gate*, *source*, and *drain*, but may have a second external gate and an external lead for the substrate

b. The IGFET body consists of two sections of semiconductor material, put together as a *channel* that connects to the source and drain terminals and a larger bulk substrate.

c. The IGFET uses a metal gate that is electrically isolated from the semiconductor channel by a thin oxide layer, such as silicon dioxide.

d. IGFETs can be either *enhancement mode* or *depletion mode* devices based on their conducting state when the bias voltage is zero, with enhancement mode IGFETs not conducting with zero bias voltage and depletion mode devices conducting at zero bias voltage.

e. Enhancement mode IGFETs are normally off devices and do not normally have a conductive channel, as indicated by the broken line between the source and the drain in the symbol for such a device.

f. Depletion mode IGFETs are normally on devices that normally have a conductive channel, as indicated by the solid line between the source and the drain in the symbol for such a device.

g. As the voltage increases in an enhancement mode IGFET, the gate becomes more positive, causing the channel conduction to improve and the drain current to increase.

h. A depletion mode IGFET will operate in the depletion mode when a negative voltage is applied to the gate and in an enhancement mode when a positive voltage is applied to the gate, so that the device is sometimes referred to as a *depletion-enhancement (DE) MOSFET*.

Information Sheet

31. Handling precautions for IGFETs

Note: When MOSFETs and other insulated gate FETs were first introduced, they were extremely sensitive to damage from electrostatic discharge and rough handling. Today's device generally have internal diodes to absorb some of the electrical dangers. However, many manufacturers still recommend that all or some of the following precautions be followed, as well as many shops and laboratories.

a. Short device leads together during handling.

b. IGFETs should only be handled at approved ESD workstations.

c. Soldering equipment used on IGFETs should be grounded.

d. IGFETs or circuitry that includes IGFETs should never be installed or removed from equipment under power.

e. IGFETs should be handled gently and never transported without adequate ESD-qualified packaging.

32. Characteristics of an ideal amplifier

a. Infinite gain

b. No output resistance

c. Infinite input resistance

33. Ways of classifying amplifiers

a. Performance characteristics

Examples: Frequency range, signal strength, power levels (wattage)

b. Number of amplifiers in circuit

Examples: Single-stage, multistage

c. Circuit configuration

Examples: Common-collector, common-source, common-emitter

d. Coupling

Examples: Capacitive, direct, transformer

Information Sheet

e. Application

Examples: Audio amplifier, video amplifier, band-pass amplifier

f. Class

Examples: Class A, B, AB, C

34. Operation of a single-stage amplifier circuit

a. The purpose of an amplifier is to provide gain—that is, the output signal will be stronger than the input signal.

b. While various devices (such as transformers) may increase the current or voltage of an output signal, they usually do so through the reduction of another characteristic, so that amplifiers are the only devices capable of simultaneous increases in voltage, current, and power.

c. Gain or amplification is expressed as a ratio between output signal and the input signal and can be expressed by formulas such as

$$A_V = \frac{V_{out}}{V_{in}}$$ for voltage gain,

$$A_I = \frac{I_{out}}{I_{in}}$$ for current gain, and

$$A_P = \frac{P_{out}}{P_{in}}$$ for power gain.

d. It is possible for the input signal to exceed the gain capabilities of the amplifier, leading to a condition where the full output waveform cannot be produced and the resulting waveform is *distorted* or *clipped*.

e. The upper limit of the input signal is referred to as the *saturation limit*.

f. The upper limit of the output signal is called the *cutoff limit*.

g. An amplifier can be tuned to a certain frequency or range of frequencies through the use of circuits that are resonant at those frequencies.

h. The power transfer of an amplifier can be maximized through impedance matching.

Information Sheet

i. Signals can be transferred from one amplifier to another by coupling the amplifiers to *multistage* or *cascaded* amplifiers.

j. Amplifier circuits can be constructed to develop a signal that will interact with the input signal to provide *feedback*.

k. If the feedback reduces the amplifier gain, it is referred to as *negative feedback*, but negative feedback can be used to improve other properties of the amplifier, such as increasing its bandwidth, change its impedances, or make the amplifier quieter.

l. The point at which an amplifier's gain drops 3 decibels below its best gain is called its *break frequency*.

m. Amplifier performance is generally represented in graphs called *load lines* that show amplifier operational status at various combinations of voltage and current.

35. Characteristics of power amplifiers

a. Amplifiers that have relatively small saturation levels are referred to as *small-signal amplifiers* or *voltage amplifiers* and their output is normally evaluated in terms of voltage.

b. Amplifiers that work with relatively large saturation points are referred to as *large-signal amplifiers* or *power amplifiers* and their output is measured in watts.

Note: If an amplifier is connected to a low-resistance load, such as a speaker, or is required to deliver more than a few milliwatts to a load, it is likely to be considered a power amplifier.

c. A power amplifier is likely to be the last stage of amplification in a multistage system.

d. Power amplifiers should have very low output impedance.

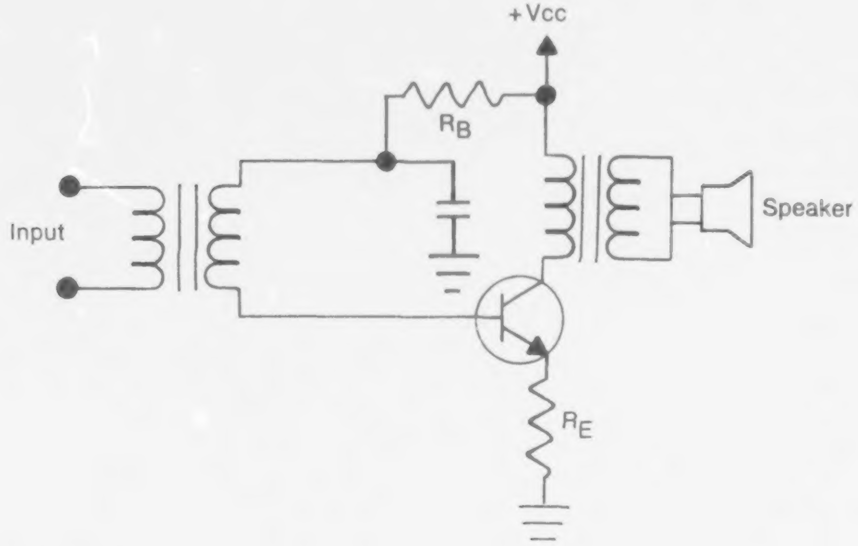
e. One evaluation of a power amplifier is its *efficiency*, which is a comparison of its output power and its DC input power, as expressed by the formula

$$\text{Efficiency} = \frac{\text{signal power output}}{\text{DC power input}} \times 100\%$$

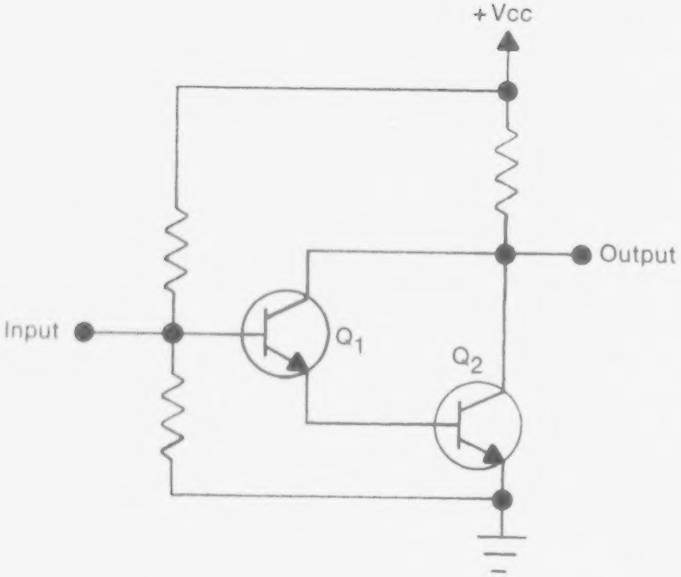
Information Sheet

36. Transistor configurations of power amplifiers

a. Single-ended

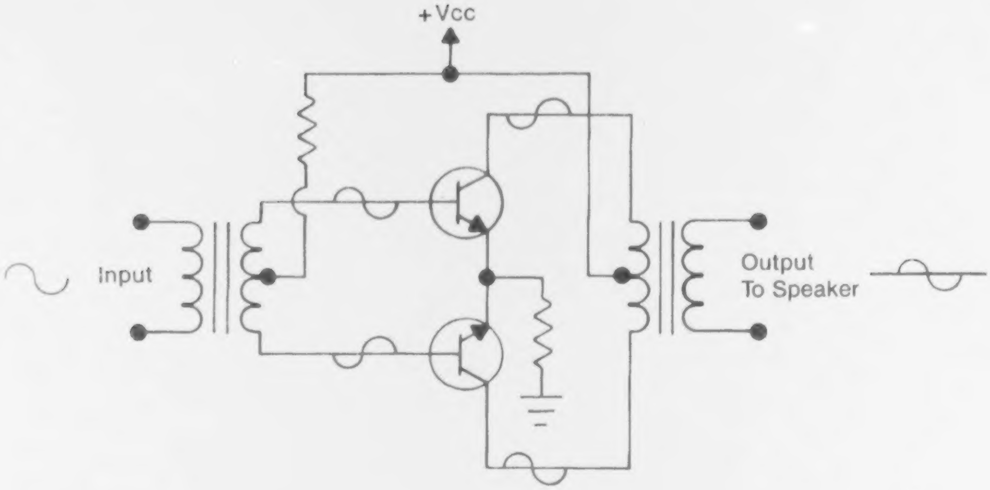

+Vcc
R_B
Input
Speaker
R_E

b. Darlington pair

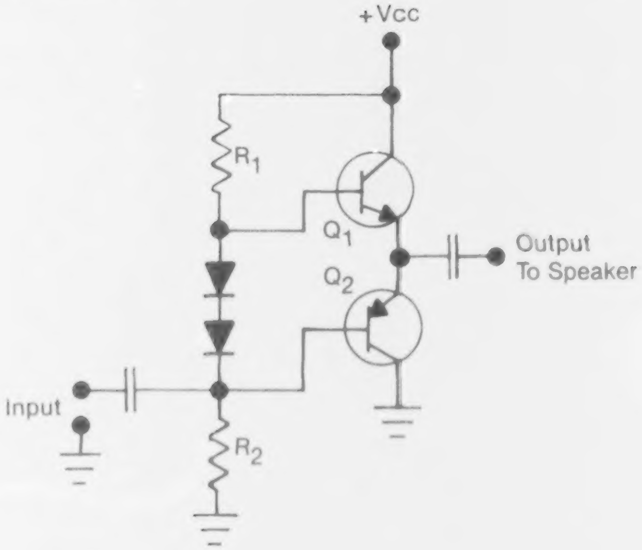

+Vcc
Output
Input
Q_1
Q_2

Information Sheet

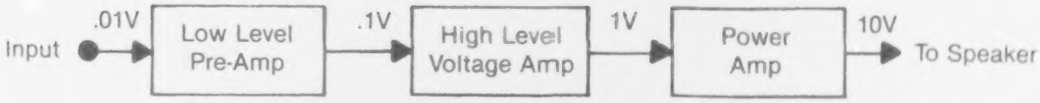
c. Push-pull


+Vcc
Input
Output
To Speaker

d. Complementary


+Vcc
R1
Q1
Q2
Output
To Speaker
Input
R2

e. Multistage


Input
.01V
Low Level Pre-Amp
.1V
High Level Voltage Amp
1V
Power Amp
10V
To Speaker

Information Sheet

37. Amplifier operating conditions

Note: While applicable to amplifiers, the operating conditions described here apply to many electrical circuits and devices. Each condition represents a portion of a voltage-conductance curve with saturation representing maximum current and cutoff representing maximum current with the active condition representing the curve between those two points.

a. Saturation—Condition in which a further increase in voltage will not lead to a significant increase in current

b. Cutoff—Condition in which a biased device will not support current flow

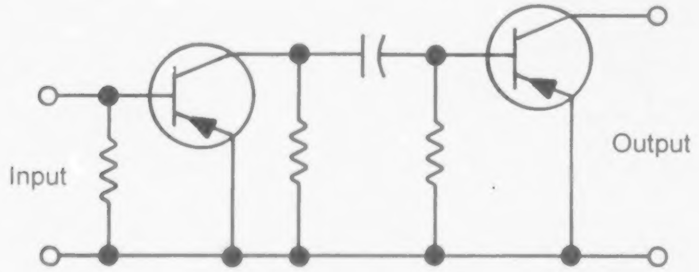
c. Active—Condition of device operation in which current flow is a function of the device's controlling current or voltage

38. Methods of coupling transistor amplifier circuits

Note: Amplifiers may be joined together through coupling to form multistage amplifiers.

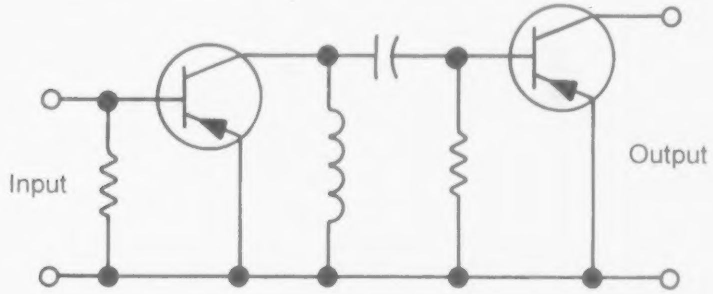
a. Resistance-capacitance (RC) coupling—Coupling that employs blocking capacitors and resistors in the supply path

Example:



b. Impedance coupling—Coupling through the use of a combination of capacitors and windings

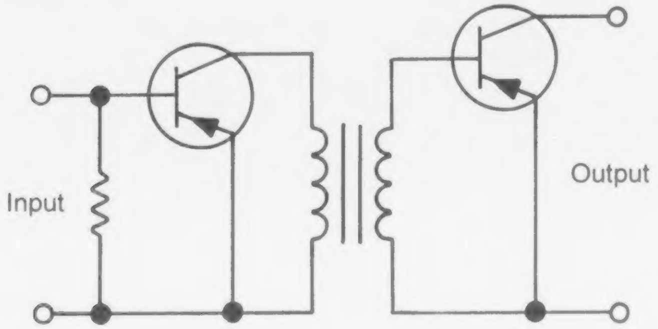
Example:



Information Sheet

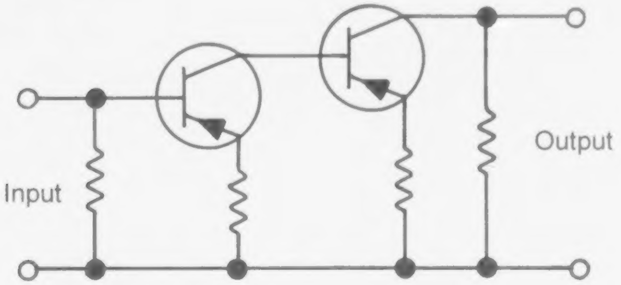
c. Transformer coupling—Coupling through inductance produced in transformers

Example:



d. Direct coupling—Coupling by actually joining separate circuits with conductors

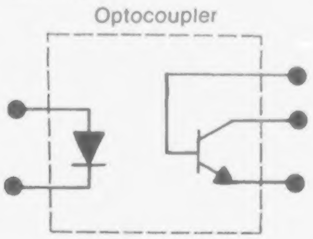
Example:



e. Optocoupling—Coupling by use of a semiconductor device that contains an infrared light-emitting diode, an enclosed light path, and a photodetector to allow signal transfer without electrical connection between the two circuits

Note: Optocouplers are also referred to as optoisolators because they electrically isolate circuits from each other.

Example:



Information Sheet

39. Classes of transistor amplifier circuits

a. Class A—Complete sine wave appears at a single transistor output

- Bias point is approximately halfway between cutoff and saturation
- Efficiency is approximately 25%
- Distortion is low
- Used mostly in small-signal amplifiers

b. Class B—Transistor is on for half of the input sine wave

- Bias point is at cutoff
- Efficiency is approximately 75%
- Distortion is high
- Used mostly in high power applications but not radio frequency operations

c. Class C—Transistor is tuned for less than half of the input sine wave

- Bias point is beyond cutoff
- Efficiency is approximately 90-95%
- Distortion is very high
- Used in radio frequency applications

d. Class AB—Transistor is tuned for more than half but less than all of the sine wave

- Bias is near but above cutoff
- Efficiency is approximately 60-65%
- Distortion is moderate
- Used in high-power applications for both audio and radio frequency applications

Information Sheet

e. Class D—AC waveform is converted to variable width pulses, with the width related to the sampled amplitude of the AC waveform

- Bias varies with waveform
- Efficiency is approximately 85-95%
- Distortion is very high
- Used in high-efficiency audio amplifiers

40. **Steps in troubleshooting transistor amplifier circuits**

a. Inspect the equipment for obvious symptoms such as burned, overheated, or broken components.

b. Check the power supply for normal operation.

c. Isolate the defective stage by making waveform checks beginning at the output and working back toward the input.

d. Make DC voltage checks with a voltmeter to find any biasing problems, checking high-power components first.

e. Test individual suspect components.

41. **Operation of unijunction transistors**

a. The unijunction transistor package has three leads referred to as *emitter*, *base 1*, and *base 2*.

b. The transistor body consists of N-type material connected to the two base leads.

c. The emitter and a small region of P-type material are embedded in the N-type material substrate.

d. UJTs exhibit *negative resistance*—that is, as the voltage in the circuit decreases, current increases.

e. The UJT is forward biased with voltage applied to the emitter, causing electrons to flow from base 1 to the emitter and a decrease in resistance between the emitter and base 1 allowing even more current flow.

f. Voltage continues to build until the UJT reaches its *standoff voltage* or *peak voltage*, which latches the transistor on and allows the current to continue to increase while the voltage decreases.

Information Sheet

g. The transistor will continue to conduct as long as the emitter current remains above a minimum value termed the transistor's *holding current*.

h. Unijunction transistors are controlled by voltage and are normally off.

i. After the UJT latches on, voltage will continue to drop until the resistance in the base 1 circuit reaches its lowest point, referred to as the *valley point*.

j. If voltage increases from the valley point, there will be a linear increase in current.

k. One of the characteristics of a unijunction transistor that may be cited in specifications is the ratio between the base 1 and base 2 resistances, which is called *intrinsic standoff ratio*, termed with the Greek letter eta (η), and is represented by the formula

$$\eta = \frac{R_{B1}}{R_{B1} + R_{B2}}$$

l. The major uses for UJTs are to trigger other devices, like SCRs, and in oscillators.

m. UJTs are not used in amplifiers.

42. Sections of an oscillator circuit

Note: In its simplest state, an oscillator is a circuit that converts DC to AC and can be made using an amplifier with a feedback circuit. However, for signal control and stability (consistency in signal frequency and amplitude) most practical electronics oscillators include additional circuits as described below.

a. Frequency determining network—Sets the oscillation frequency

Examples: Tank circuit, crystal

Note: For frequencies of less than 1 MHz, many electronic oscillators use RC networks, while those required to produce higher frequencies usually include LC networks or crystal controllers.

b. Amplifier stage—Replaces circuit losses

c. Positive feedback circuit—Supplies a regenerative signal back to the frequency determining components to maintain oscillations

Information Sheet

d. DC power supply—Supplies the frequency determining network and amplifier with electrical energy

Note: The output frequency of some oscillators is directly controlled by the DC input and are called *voltage-controlled oscillators* or *VCOs*. Often this is done by providing one or more varactors in the frequency determining network.

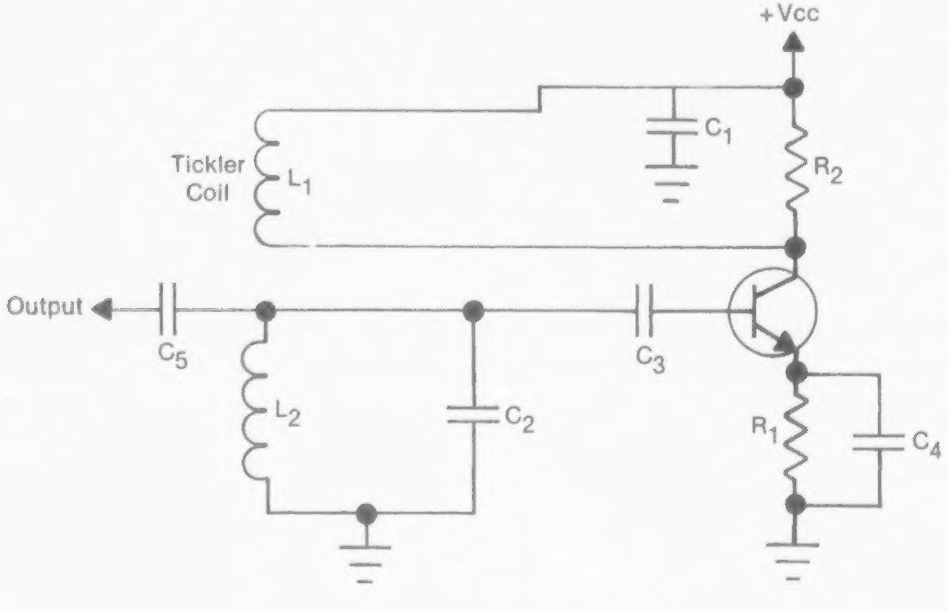
e. Self-starting oscillator device—Generates the oscillations

43. Common configurations of oscillators

Note: The descriptions and examples below are intended to introduce you to the general structure and operation of some common oscillator circuits. The actual constructions of these circuits can vary greatly, and their names are primarily applicable to their basic operating concept.

a. Armstrong oscillator—Uses a small coil referred to as a *tickler coil* wired in series with or as a shunt to a bipolar transistor amplifier to provide regenerative feedback through inductive coupling

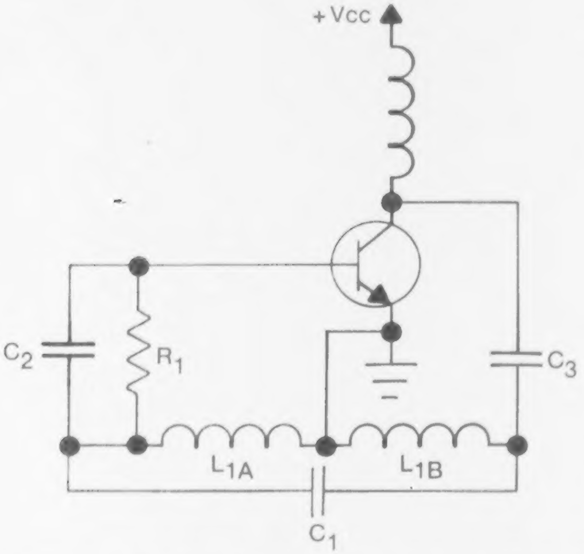
Example:



Information Sheet

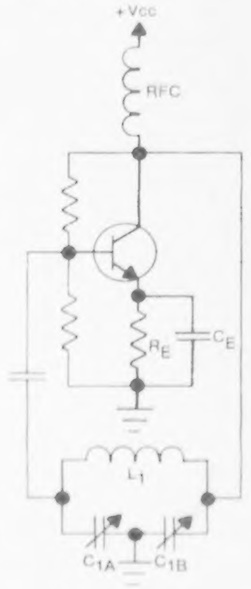
b. Hartley oscillator—Uses a tapped coil in series with or as a shunt to a bipolar transistor or FET amplifier for in-phase feedback

Example:


+Vcc
C_2
R_1
C_3
L_{1A}
L_{1B}
C_1

c. Colpitts oscillator—Uses a tank circuit that is divided into input and feedback portions by a capacitive voltage divider with either a bipolar or FET amplifier

Example:


+Vcc
RFC
R_E
C_E
L_1
C_{1A}
C_{1B}

Information Sheet

44. Descriptions of thyristors

Note: The following devices are often referred to by the generic term *thyristors*, though some authorities restrict that term to four-layer (PNPN) devices that exhibit strong switching characteristics.

a. Silicon-controlled rectifier (SCR)—A gated diode that does not begin forward conduction until triggered

b. Complementary silicon-controlled rectifier (CSCR)—An SCR that is gated to the anode

c. Light-activated silicon-controlled rectifier (LASCR)—An SCR that can be triggered with light

d. Silicon-controlled switch (SCS)—An SCR that is gated to both the anode and cathode

e. Silicon unilateral switch (SUS)—An SCR with an internal zener circuit on the anode gate

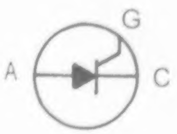
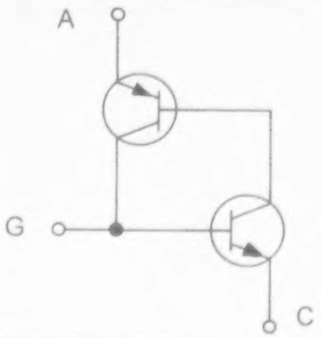
f. Silicon bilateral switch (SBS)—An SCR with an internal zener on each gate

g. Diac—A bidirectional device used to gate other devices

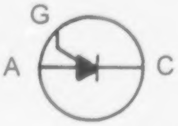
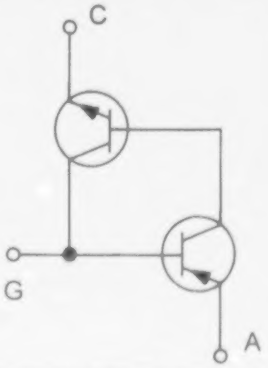
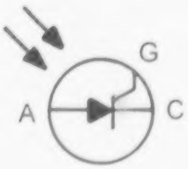
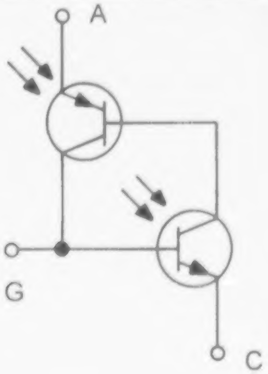
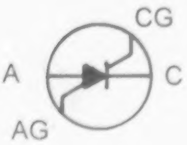
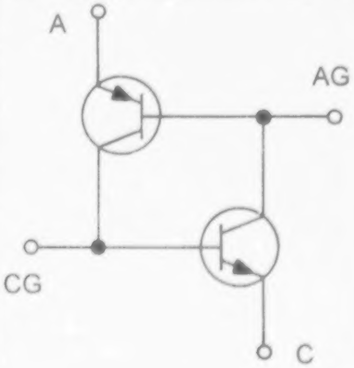
Note: On bidirectional devices, the concept of anode and cathode loses its applicability. Thus, the leads on such devices are generally referred to as *main terminals* or *MTs*.

h. Triac—A diac with a gate

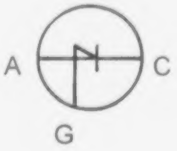
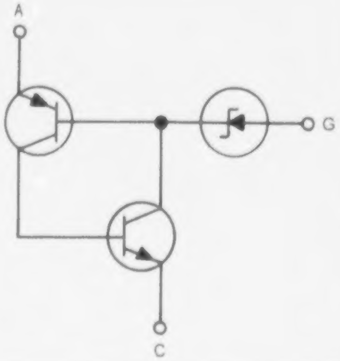
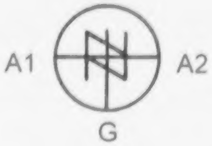
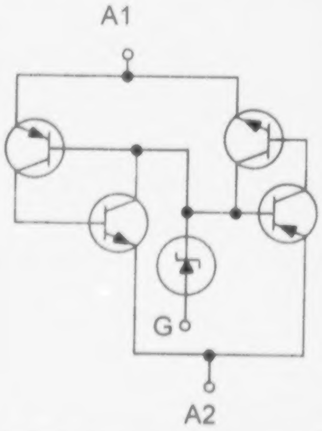
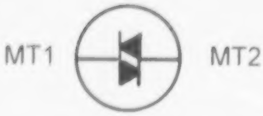
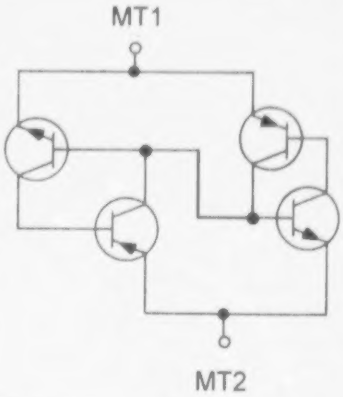
45. Symbols and electrical equivalents for thyristors

Thyristor	Symbol	Electrical Equivalent
Silicon-controlled rectifiers		
• SCR		

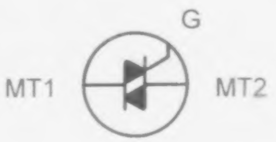
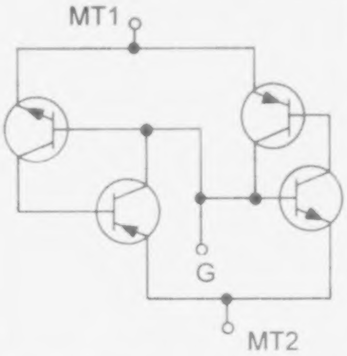
Information Sheet

Thyristor	Symbol	Electrical Equivalent
• CSCR		
• LASCR		
Silicon-controlled switches		
• Silicon-controlled switch		

Information Sheet

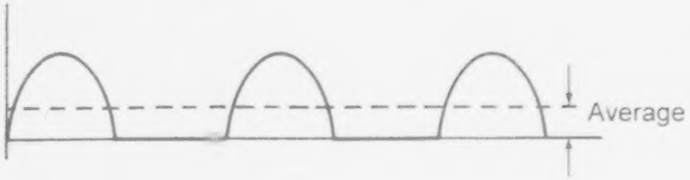
Thyristor	Symbol	Electrical Equivalent
- Unilateral switch		
- Bilateral switch		
Bidirectional		
- Diac		

Information Sheet

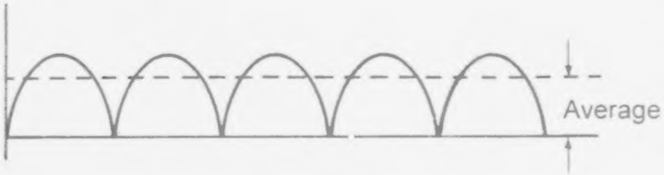
Thyristor	Symbol	Electrical Equivalent
- Triac		

46. Rectified waveforms

a. Half-wave

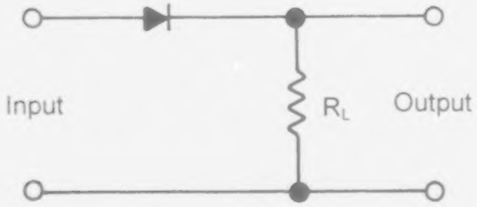


b. Full-wave



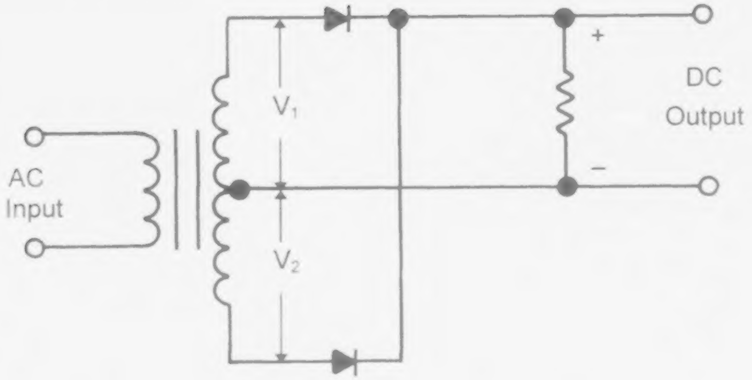
47. Rectifier circuits

a. Half-wave rectifier

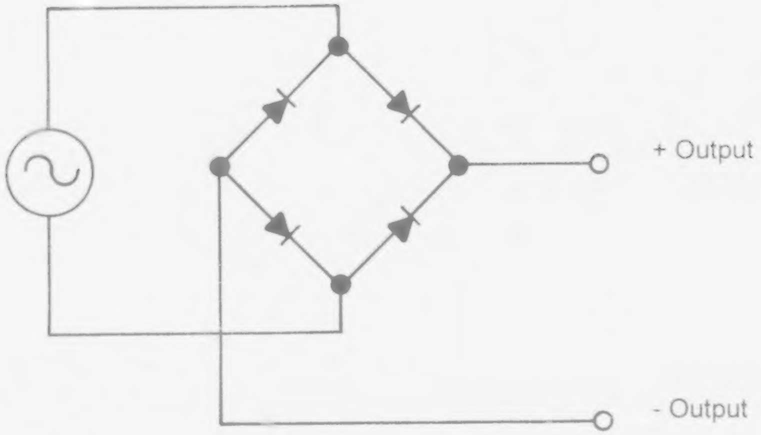

Input
R_L
Output

Information Sheet

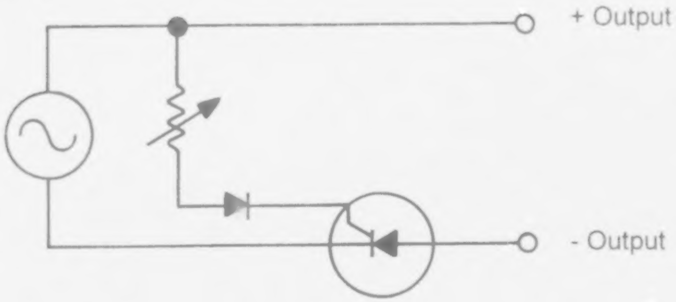
b. Full-wave rectifier


+
DC
Output
−
AC
Input
V_1
V_2

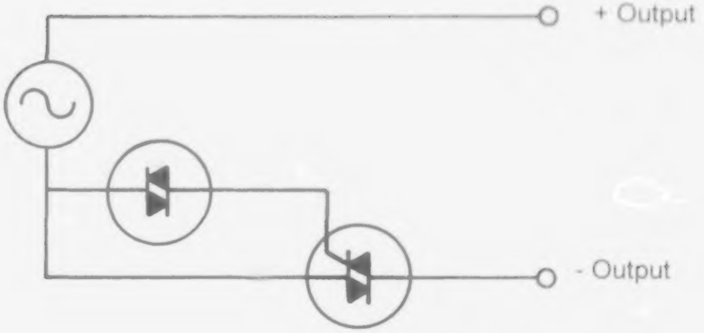
c. Bridge rectifier


+ Output
- Output

d. SCR

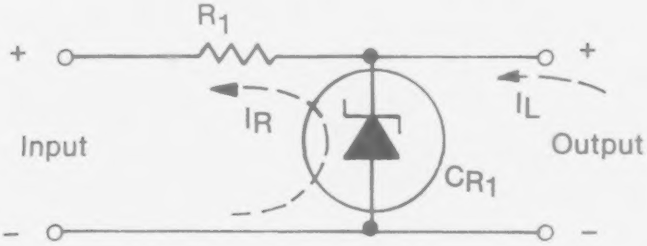

+ Output
- Output

e. Triac

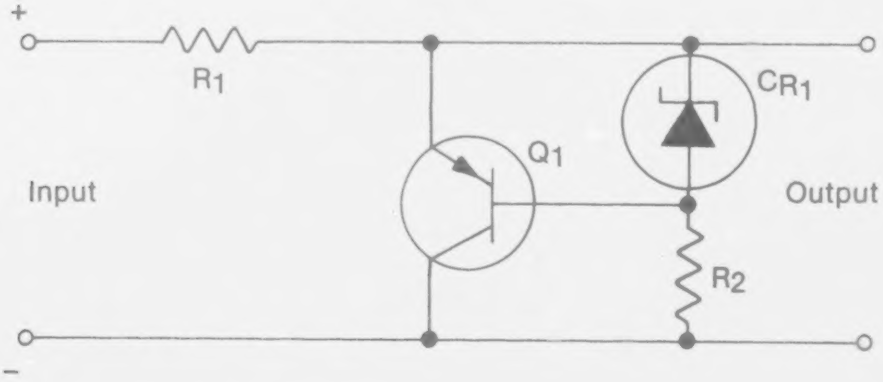

+ Output
- Output

48. Schematics for voltage regulators

a. Zener diode shunt regulator

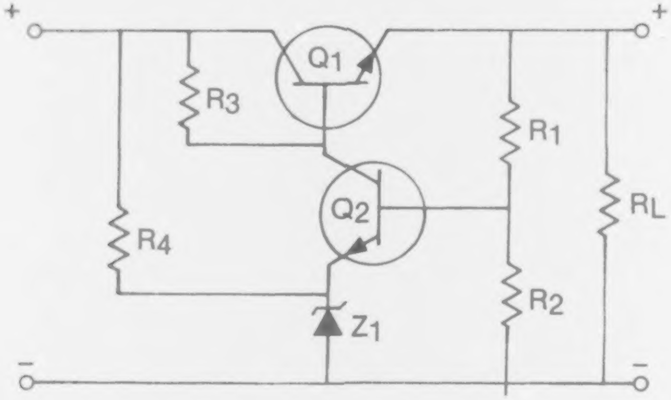

R1
+
+
IR
IL
Input
Output
CR1
–
–

b. Transistor shunt regulator

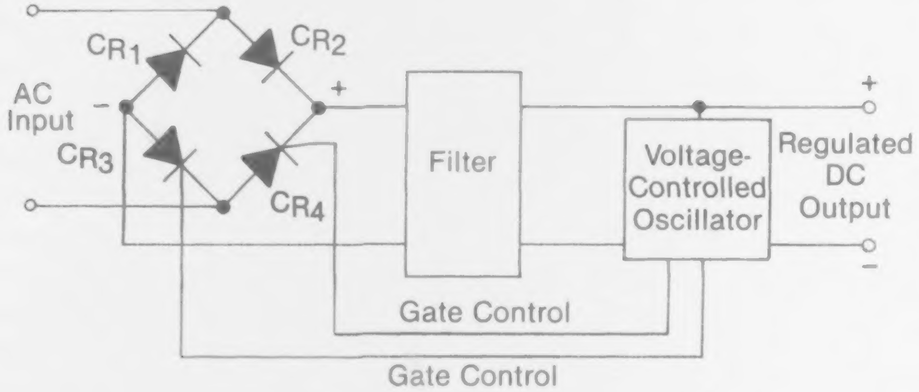

+
R1
CR1
Q1
Input
Output
R2
–

Information Sheet

c. Transistor series regulator


+
+
Q1
R3
R1
Q2
RL
R4
R2
Z1
–
–

d. Thyristor regulator


CR1
CR2
AC Input
–
+
CR3
CR4
Filter
Voltage-Controlled Oscillator
+
Regulated DC Output
–
Gate Control
Gate Control

Discrete Semiconductor Devices and Circuits
Unit 1

Assignment Sheet 1—Use Resource Materials to Determine Pin Configurations for Common Types of Semiconductor Devices

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
• Directions have been followed	______
• Minimum of 80 percent of answers are correct	______

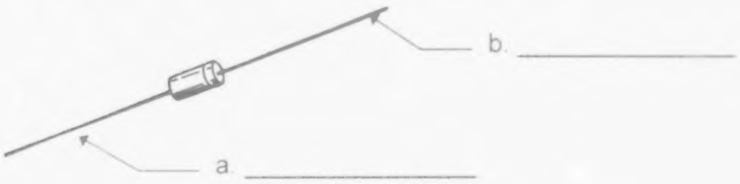
Note: Each correct answer is worth 10 points.

Introduction: One of the important requirements for the proper operation of an electronic circuit is that the discrete components be correctly installed. For some components that have two leads and are not polarized, such as most resistors, lead identification is not important. However, most semiconductor devices must be installed in their circuits so that the leads connect to specific conductors. Thus, a technician who is fabricating circuits or installing replacement parts must be able to correctly orient the part for installation. Similarly, a technician who is testing a circuit must be able to identify the leads to verify circuit functioning.

A technician does not necessarily have to memorize the lead arrangements for semiconductor devices, though with experience you will become familiar with the more common package arrangements. However, work in the electronics field will require you to be able to use resources such as data sheets, catalogs, and handbooks to identify the pins of the components with which you will work. This assignment sheet will provide you with practice in using those resources to identify the leads on discrete semiconductor devices.

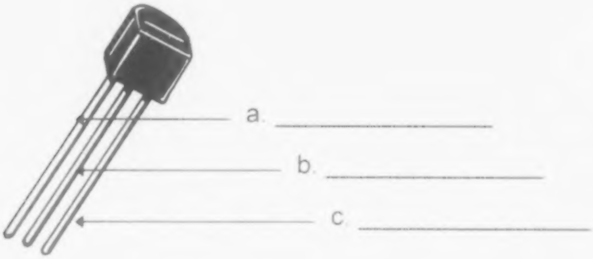
Directions: Study each of the illustrations of semiconductor components below and identify the leads as requested. Write your answers in the spaces provided.

1. Label the cathode and anode.

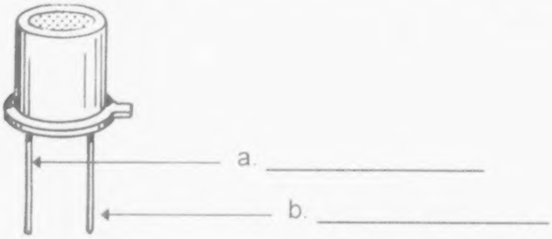


Assignment Sheet 1

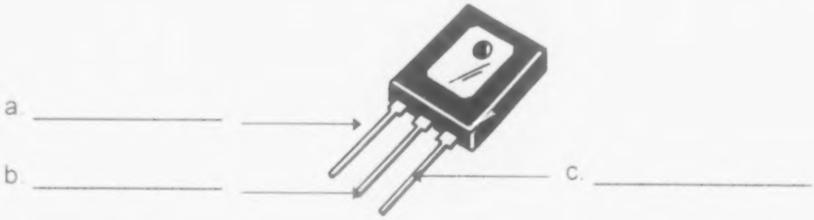
2. The transistor below is an MPSA20 in a TO-92 case. Label the base, collector, and emitter.



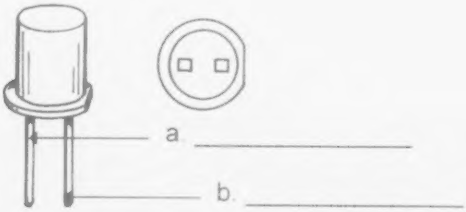
3. The device below is a photodiode. Label the cathode and anode.



4. Pictured below is a 2N4442 SCR. Label the anode, cathode, and gate.

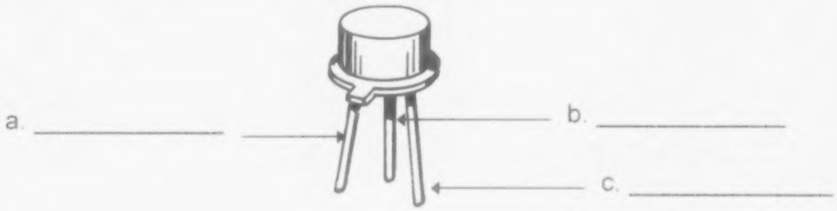


5. The device below is an FLV150 red GaSaP light-emitting diode. Label the anode and cathode.

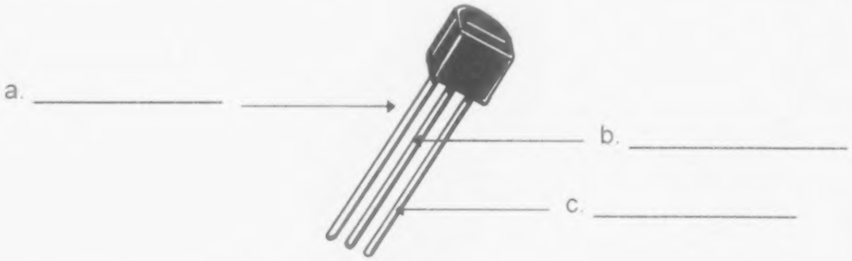


Assignment Sheet 1

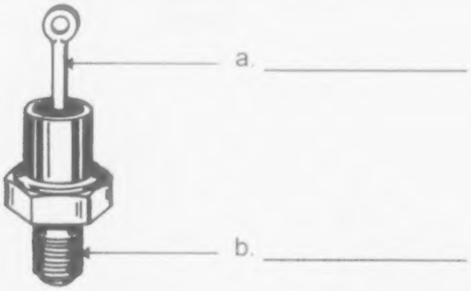
6. The transistor below is in a TO-39 case. Label the base, collector, and emitter.



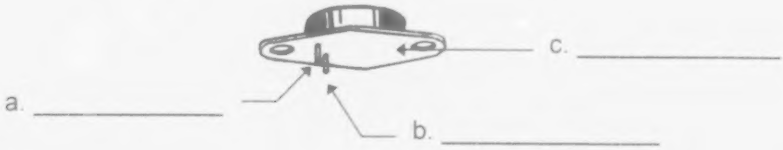
7. The field-effect transistor illustrated below is a 2N5458 in a TO-92 case. Label the drain, gate, and source leads.



8. This diode has a threaded metal case. Label the anode and cathode.

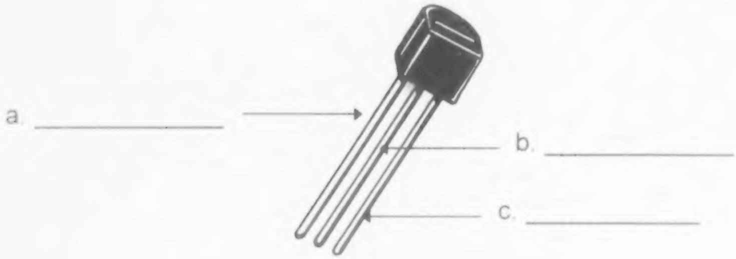


9. The metal case for this transistor is classified as a TO-3. Label the base, collector, and emitter.



Assignment Sheet 1

10 The 2N4870 below is a UJT in a TO-92 case. Label base 1, base 2, and emitter.



Discrete Semiconductor Devices and Circuits
Unit 1

Assignment Sheet 2—Interpret Functions of Electronic Circuits Constructed from Discrete Semiconductor Components

Name ____ Overall Rating ____________

Evaluation criteria	**Rating**
• Directions have been followed	________
• Minimum of 85 percent of answers are correct	________
Note: Each correct answer is worth 2.5 points.	

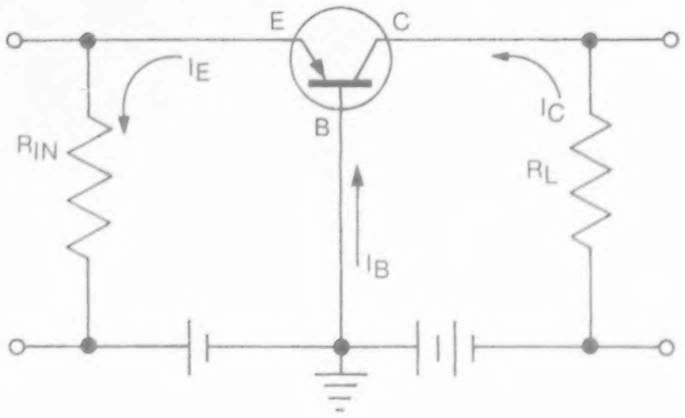
Introduction: A basic skill of the electronics technician is the ability to understand the function of electronic circuits by analyzing the configuration of the components in the circuit. While circuit diagrams and schematics are often available, they are not the total answer because equipment is not always built like the schematics. Different parts may be used or parts that have been replaced may differ from those in the original design. The design may have changed without the revision being updated in the schematic. The arrangement of parts and subcircuits on paper may differ greatly from the actual PCBs and other hardware. Failed parts, shorts, opens, and other defects may cause the circuit performance to be radically different than that described on the schematic. For these reasons and more, a good technician is able to interpret the general operational functions of a circuit through testing and analysis. This assignment sheet will provide you with practice in that skill in working with discrete semiconductor components.

Directions: Study each circuit shown and answer the questions that accompany it. Write your answers in the spaces provided.

Note: Schematics and questions begin on the next page.

Assignment Sheet 2

1.



a. What type of circuit is shown?

_______(1) Rectifier

_______(2) Amplifier

_______(3) Oscillator

_______(4) Voltage regulator

b. What is the principle type of component used?

_______(1) NPN transistor

_______(2) PNP transistor

_______(3) FET

_______(4) Unijunction transistor

c. What is the configuration of the circuit?

_______(1) Common base

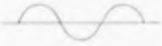
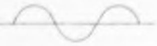
_______(2) Common emitter

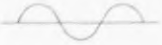
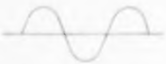
_______(3) Common collector

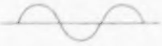
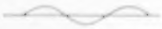
_______(4) Common drain

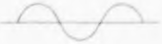
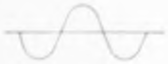
Assignment Sheet 2

d. Which of the following is the most likely comparison of input and output for the circuit?

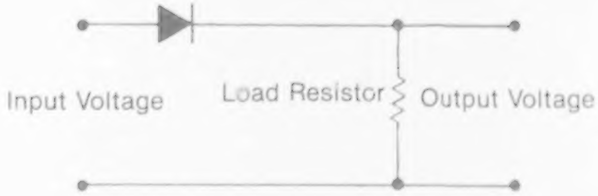
_______(1) From  to 

_______(2) From  to 

_______(3) From  to 

_______(4) From  to 

2.


Input Voltage
Load Resistor
Output Voltage

a. What type of circuit is shown?

_______(1) Rectifier

_______(2) Amplifier

_______(3) Oscillator

_______(4) Voltage regulator

b. What is the principle type of component used?

_______(1) Diac

_______(2) Zener diode

_______(3) Triac

_______(4) Bipolar diode

Assignment Sheet 2

c. What is the configuration of the circuit?

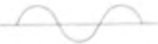
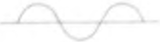
________(1) Half-wave

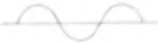
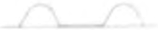
________(2) Zener shunt

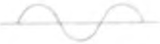
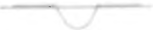
________(3) Colpitts

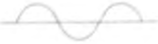
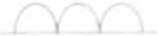
________(4) Full-wave

d. Which of the following is the most likely comparison of input and output for the circuit?

________(1) From  to 

________(2) From  to 

________(3) From  to 

________(4) From  to 

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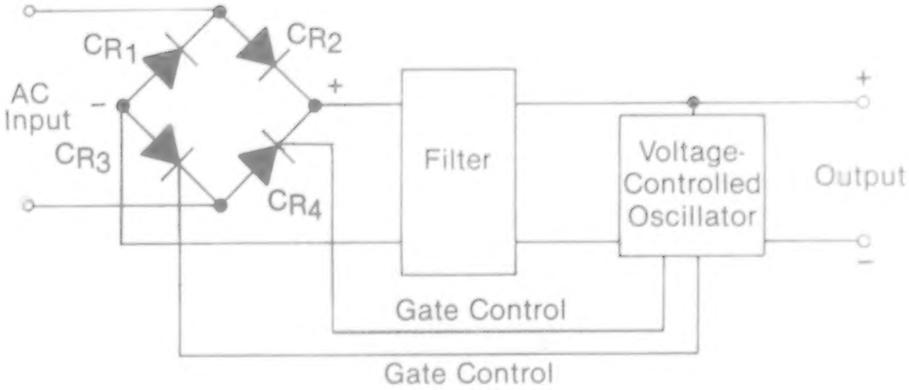


CR1
CR2
AC Input
-
+
CR3
CR4
Filter
Voltage-Controlled Oscillator
+
Output
-
Gate Control
Gate Control

Assignment Sheet 2

a What type of circuit is shown?

________(1) Rectifier

________(2) Amplifier

________(3) Oscillator

________(4) Voltage regulator

b. What is the principle type of component used?

________(1) SCR and diode

________(2) SCR and diac

________(3) SCR and zener diode

________(4) Triac and zener diode

c. What is the configuration of the circuit?

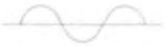
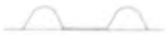
________(1) Zener shunt

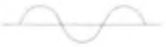
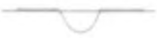
________(2) Wein bridge

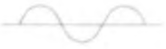
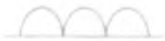
________(3) Thyristor

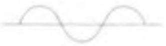
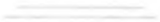
________(4) Zener series

d. Which of the following is the most likely comparison of input and output for the circuit?

________(1) From  to 

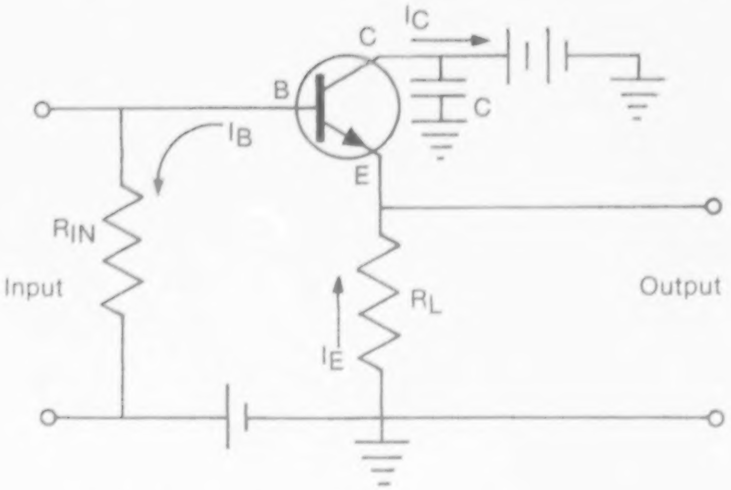
________(2) From  to 

________(3) From  to 

________(4) From  to 

Assignment Sheet 2

4



a. What type of circuit is shown?

_______(1) Rectifier

_______(2) Amplifier

_______(3) Oscillator

_______(4) Voltage regulator

b. What is the principle type of component used?

_______(1) NPN transistor

_______(2) PNP transistor

_______(3) FET

_______(4) Unijunction transistor

c. What is the configuration of the circuit?

_______(1) Common base

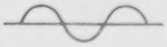
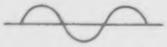
_______(2) Common emitter

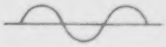
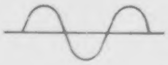
_______(3) Common collector

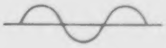
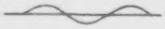
_______(4) Common source

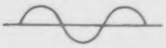
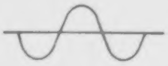
Assignment Sheet 2

d. Which of the following is the most likely comparison of input and output for the circuit?

_______(1) From  to 

_______(2) From  to 

_______(3) From  to 

_______(4) From  to 

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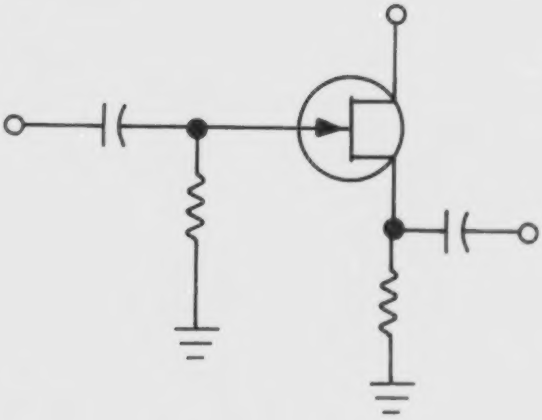


a. What type of circuit is shown?

_______(1) Rectifier

_______(2) Amplifier

_______(3) Oscillator

_______(4) Voltage regulator

Assignment Sheet 2

b. What is the principle type of component used?

_______(1) NPN transistor

_______(2) PNP transistor

_______(3) FET

_______(4) Unijunction transistor

c. What is the configuration of the circuit?

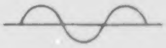
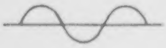
_______(1) Common base

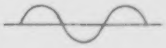
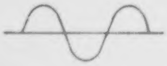
_______(2) Common source

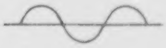
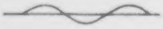
_______(3) Common gate

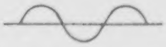
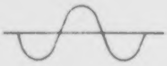
_______(4) Common drain

d. Which of the following is the most likely comparison of input and output for the circuit?

_______(1) From  to 

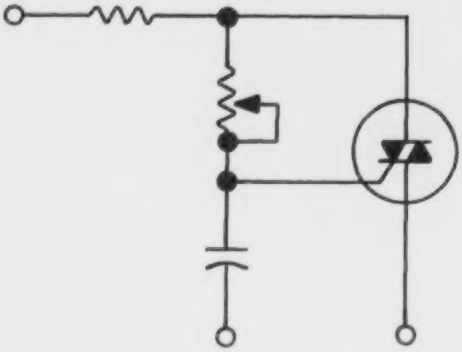
_______(2) From  to 

_______(3) From  to 

_______(4) From  to 

Assignment Sheet 2

6.



a. What type of circuit is shown?

_______(1) Rectifier

_______(2) Amplifier

_______(3) Oscillator

_______(4) Voltage regulator

b. What is the principle type of component used?

_______(1) SCR

_______(2) Triac

_______(3) Diac

_______(4) Bidirectional zener diode

c. What is the configuration of the circuit?

_______(1) Colpitts

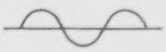
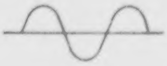
_______(2) Hartley

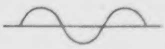
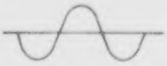
_______(3) Triac

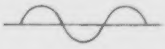
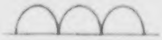
_______(4) Armstrong

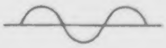
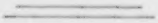
Assignment Sheet 2

d. Which of the following is the most likely comparison of input and output for the circuit?

_______(1) From  to 

_______(2) From  to 

_______(3) From  to 

_______(4) From  to 

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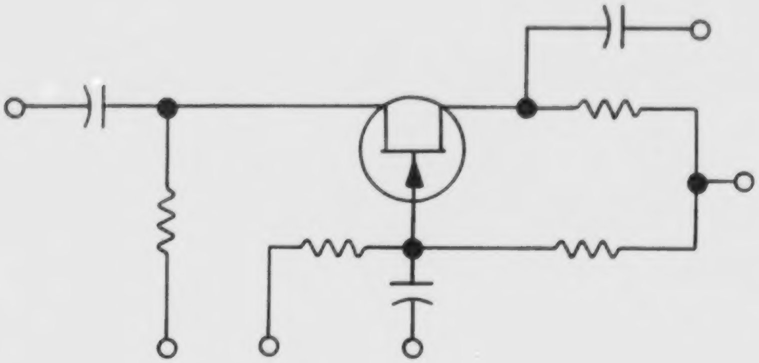


a. What type of circuit is shown?

_______(1) Rectifier

_______(2) Amplifier

_______(3) Oscillator

_______(4) Voltage regulator

Assignment Sheet 2

b. What is the principle type of component used?

_______(1) NPN transistor

_______(2) PNP transistor

_______(3) FET

_______(4) Unijunction transistor

c. What is the configuration of the circuit?

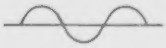
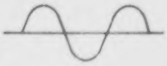
_______(1) Common base

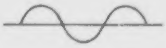
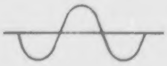
_______(2) Common gate

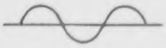
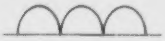
_______(3) Common source

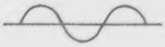
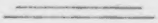
_______(4) Common drain

d. Which of the following is the most likely comparison of input and output for the circuit?

_______(1) From  to 

_______(2) From  to 

_______(3) From  to 

_______(4) From  to 

Assignment Sheet 2

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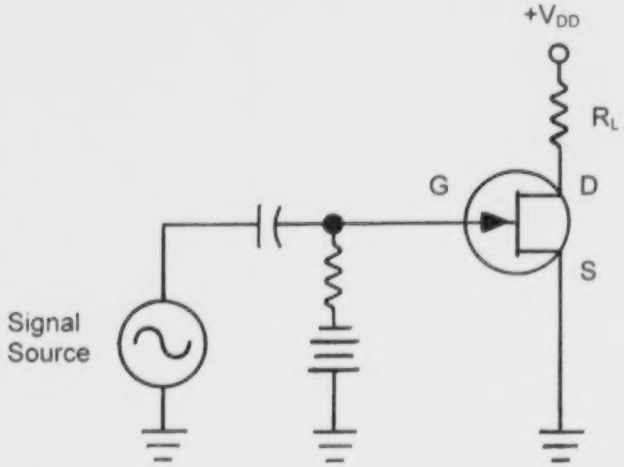


a. What type of circuit is shown?

_______(1) Rectifier

_______(2) Amplifier

_______(3) Oscillator

_______(4) Voltage regulator

b. What is the principle type of component used?

_______(1) NPN transistor

_______(2) PNP transistor

_______(3) FET

_______(4) Unijunction transistor

c. What is the configuration of the circuit?

_______(1) Common collector

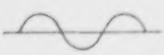
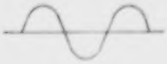
_______(2) Common emitter

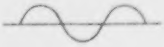
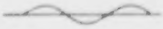
_______(3) Common source

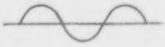
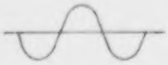
_______(4) Common drain

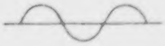
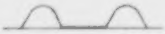
Assignment Sheet 2

d. Which of the following is the most likely comparison of input and output for the circuit?

_______(1) From  to 

_______(2) From  to 

_______(3) From  to 

_______(4) From  to 

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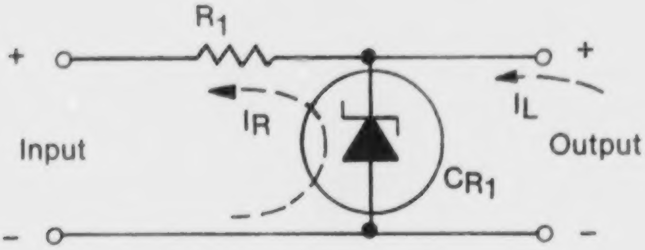


a. What type of circuit is shown?

_______(1) Rectifier

_______(2) Amplifier

_______(3) Oscillator

_______(4) Voltage regulator

b. What is the principle type of component used?

_______(1) Zener diode

_______(2) Bipolar diode

_______(3) Diac

_______(4) SCR

Assignment Sheet 2

c. What is the configuration of the circuit?

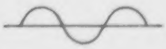
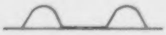
________(1) Zener shunt

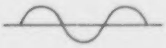
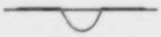
________(2) Zener series

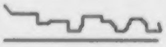
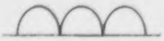
________(3) Thyristor shunt

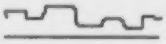
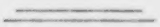
________(4) Thyristor series

d. Which of the following is the most likely comparison of input and output for the circuit?

________(1) From  to 

________(2) From  to 

________(3) From  to 

________(4) From  to 

Assignment Sheet 2

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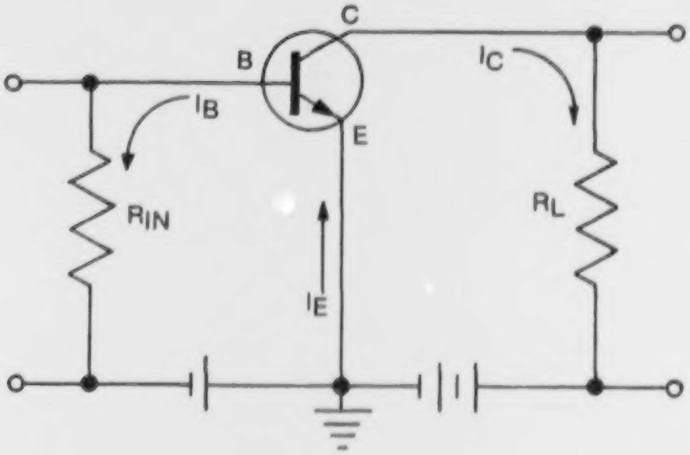


a. What type of circuit is shown?

_______(1) Rectifier

_______(2) Amplifier

_______(3) Oscillator

_______(4) Voltage regulator

b. What is the principle type of component used?

_______(1) NPN transistor

_______(2) PNP transistor

_______(3) FET

_______(4) Unijunction transistor

c. What is the configuration of the circuit?

_______(1) Common base

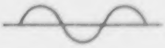
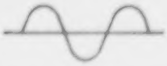
_______(2) Common emitter

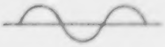
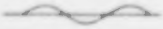
_______(3) Common collector

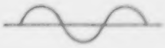
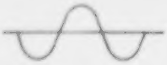
_______(4) Common drain

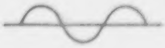
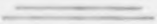
Assignment Sheet 2

d. Which of the following is the most likely comparison of input and output for the circuit?

_______(1) From  to 

_______(2) From  to 

_______(3) From  to 

_______(4) From  to 

Discrete Semiconductor Devices and Circuits
Unit 1

Assignment Sheet 3—Label the Parts of a Transistor Circuit

Name ______________________________ Overall Rating ____________

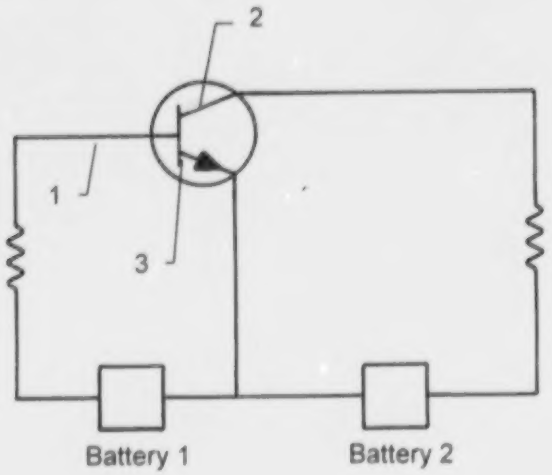
Evaluation criteria	**Rating**
• Directions have been followed	________
• Minimum of 85 percent of answers are correct	________

Note: Each correct answer is worth 20 points.

Introduction: In order to recognize how transistor circuits operate, the technician must understand how electricity flows through the transistor and related circuitry. Understanding electrical flow in a schematic or an actual circuit begins with being able to identify the leads of the components involved and what happens to electrical flow internal to semiconductor components. In this assignment sheet, you will analyze a common transistor circuit to determine how it is constructed and how it operates.

Directions: Study the circuits illustrated and answer the questions on the following pages. Write your answers in the spaces provided.

Assignment Sheet 3



1. Is the transistor in the circuit an NPN or PNP transistor? __________

2. Identify the leads of the transistor by writing the correct numbers in the spaces provided.

_______a. Collector

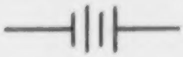
_______b. Base

_______c. Emitter

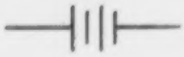
3. Which of the symbols below represent the correct battery polarities for Battery 1 and Battery 2?

Note: Write the numbers in the spaces provided. If one symbol is correct for both batteries, write both numbers in that space.

_______a.



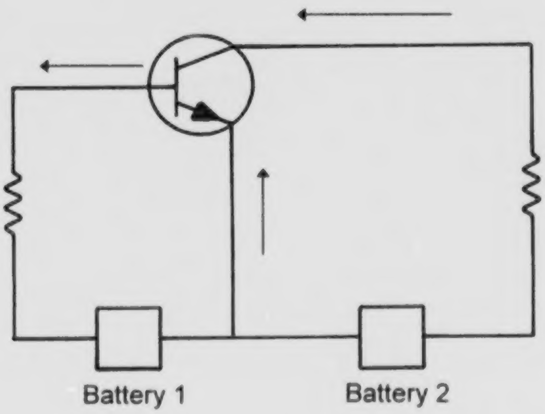
_______b.



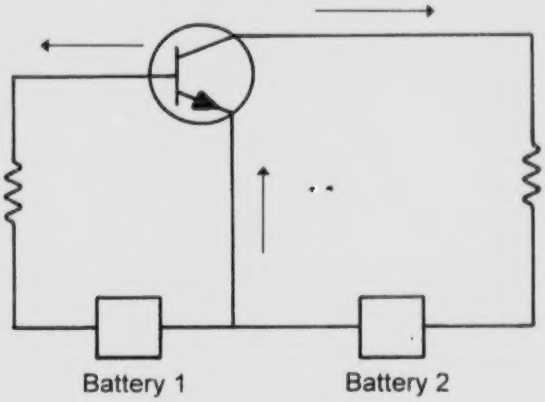
Assignment Sheet 3

4. Which of the following schematics shows the correct flow of current for the circuit?

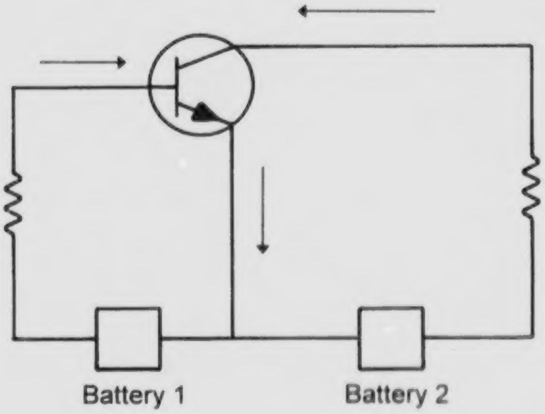
_______a.


Battery 1
Battery 2

_______b.


Battery 1
Battery 2

_______c.


Battery 1
Battery 2

Assignment Sheet 3

5. If the values for I_B and I_C are 60 mA and 35 mA respectively, what is the value of I_E?

_______a. 95 mA

_______b. 25 mA

_______c. 70 mA

Discrete Semiconductor Devices and Circuits
Unit 1

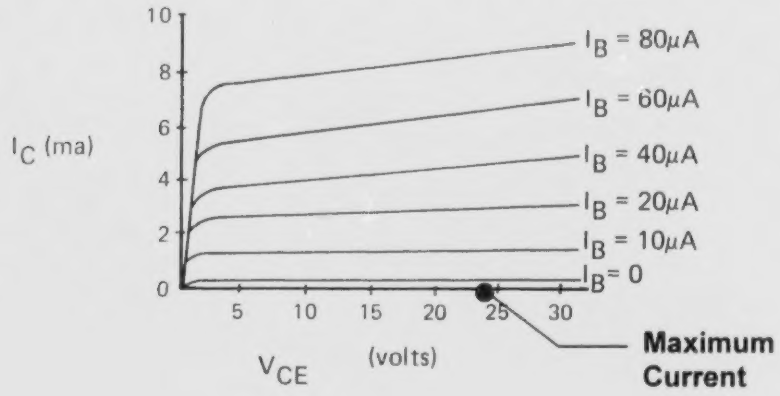
Assignment Sheet 4—Construct a Load Line for a Common-Emitter Amplifier Circuit

Name ______________________________ Overall Rating ____________

Evaluation criteria	**Rating**
• Directions have been followed	________
• Minimum of 80 percent of answers are correct	________
Note: Each correct answer is worth 10 points.	

Introduction: Transistor manufacturers graph transistor performance with characteristic curves, with sets of curves for each lead that are referred to as the collector family of curves, base family of curves, and emitter family of curves. These curves are useful in determining the expected behavior of transistors in actual circuits. This is done by plotting a *load line* for the circuit. To plot the load line, the technician must know the values of the supply voltage and the load resistor. The supply voltage is the maximum voltage for the circuit because no matter what the other values are, the voltage will not exceed the applied voltage. So this designates one end of the load line. This can be seen in the following example.

The graph below shows the collector curves for a particular transistor. Assume that the applied voltage is 24 volts. We can mark one end of the load line by marking the 24-volt point on the horizontal axis, as shown in the illustration. We can label this V_{CE} because it shows the maximum applied voltage. This point is known as the circuit *maximum current* because there is no current beyond this point.



Assignment Sheet 4

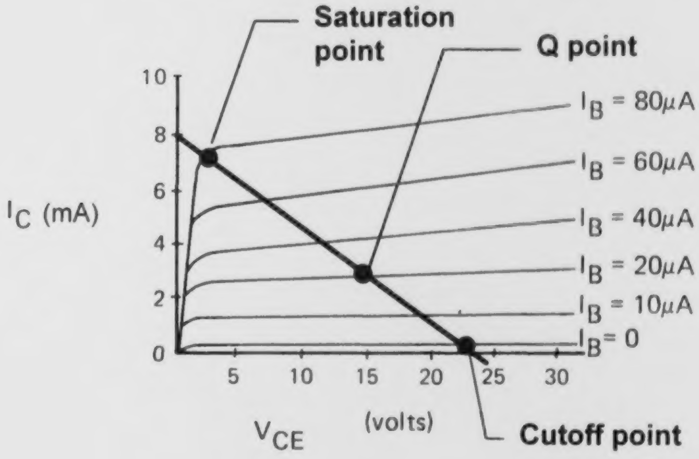
The next point needed for the load line is the maximum current. This shows what the current would be if the voltage were as low as it can go, which is 0 volts. Using Ohm's law and a maximum voltage of 24 volts, we see why the value of the load resistor is important as the load resistor will be the other part of the equation that will allow us to calculate maximum current. If the circuit uses a 3 Kohm resistor, then the maximum current would be equal to

$$I_{sat} = \frac{V_{CC}}{R_L} = \frac{24V}{3K\Omega} = 8 \text{ mA}$$

If we connect the two points that represent maximum current and maximum voltage, we have the circuit's load line. Each intersection between the load line and the collector curves shows what the collector current and voltage will be for a given base current. Three of these intersection points are especially important in defining the operation of the transistor. These are the operation of the transistor at greatest voltage, greatest current, and at the midpoint between these values. As can be seen from the load line below, with the base current at 80 μA, I_C will be approximately 7.5 mA. This point is called the *saturation point* because the collector current cannot exceed this value, no matter what the input signal values are. At the saturation point, the V_{CE} will be around 2.5 V.

The value collector curve is 0 μA. The point at which the load line intersects the lowest value collector curve represents the lowest possible voltage and is referred to as the *cutoff point* beyond which voltage will not increase no matter what input voltage is used. At the cutoff point in our example, I_C is approximately 0.25 mA and V_{CE} is around 23 V.

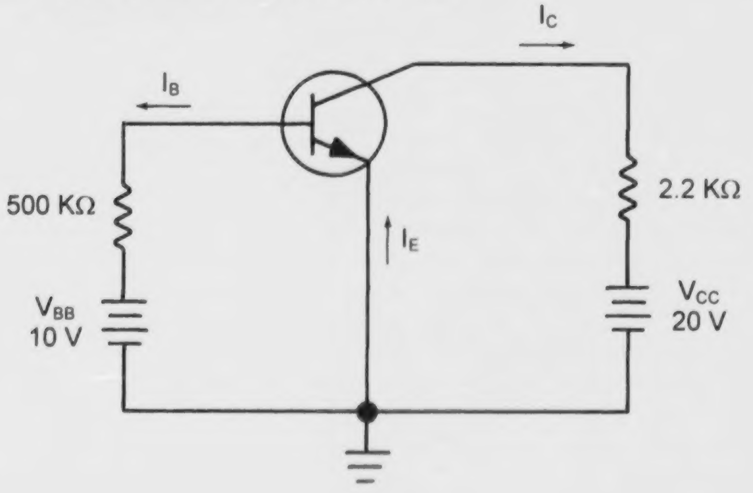
A third point that can be determined from the load line is the *quiescent point* or *Q point*. This is the value of most efficient transistor operation and rests at the middle of the load line. Because the curve graph shows six curves, the Q point would generally be marked closer to the cutoff point than to the saturation point. Thus, in this case, the Q point would be on the I_B = 20 μA curve and would result in an I_C value of around 2.7 mA and a V_{CE} of approximately 16 V.

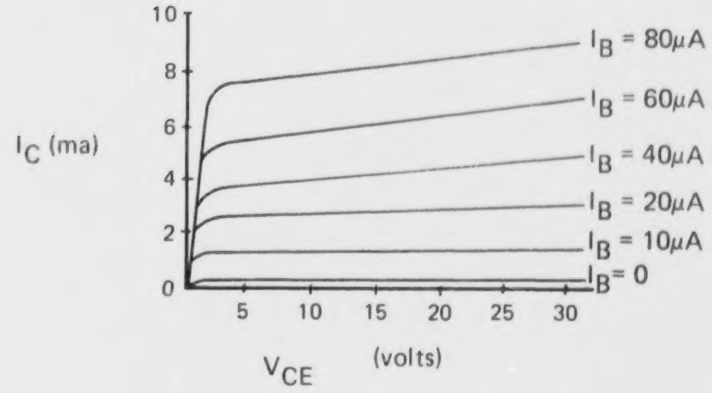


Assignment Sheet 4

Note: Some texts may refer to the maximum current as the saturation point and the maximum voltage as the cutoff point. These are the theoretical values, while the load line defines the operational values. This difference in terminology is not significant as operational saturation points and cutoff points must be used for practical applications.

Directions: Study the circuit below then plot the load line for the values given. Mark the saturation, cutoff, and Q points. Write down the values for I_C and V_{CE} for the saturation, cutoff, and Q points. Write your answers in the spaces provided.





		I_C	V_{CE}
1.	At saturation point		
2.	At Q point		
3.	At cutoff point		

Discrete Semiconductor Devices and Circuits
Unit 1

Assignment Sheet 5—Calculate the Gain of Amplifier Circuits

Name ______________________________________ Overall Rating ____________

Evaluation criteria	Rating
• Directions have been followed	________
• Minimum of 80 percent of answers are correct	________
Note: Each correct answer is worth 10 points.	

Introduction: The primary function of an amplifier in an electronic circuit is to provide gain. Amplifiers are valuable components because they allow electronic circuits to operate at relatively low power levels yet can be used to boost signal strength as required. This is particularly important in circuits that use semiconductors and battery power. Electronic engineers must be able to calculate gain requirements and design amplifier circuits that can meet those requirements. Technicians need to be able to calculate gain in order to verify whether amplifiers are functioning at the required level, to set up test circuits, and to determine other expected circuit values when analyzing equipment performance.

Gain is the ratio between the values of the input signal compared to those of the output signal. These values can be voltage, current, or power. Generally, for small signal amplifiers, gain is expressed as voltage gain. Large-signal amplifiers usually have gain expressed as power gain.

The formulas for determining voltage and power gain are fairly straightforward. If the input of a small-signal amplifier is 2 volts and the output is 6 volts, then its voltage gain is

$$A_V = \frac{\text{output voltage}}{\text{input voltage}} = \frac{6\text{ V}}{2\text{ V}} = 3$$

For a power amplifier (large-signal) with an input wattage of 1 watt and an output of 10 watts, the gain would be

$$A_P = \frac{\text{output wattage}}{\text{input wattage}} = \frac{P_{out}}{P_{in}} = \frac{10\text{ W}}{1\text{ W}} = 10$$

Directions: Use the equations presented to determine the requested values in the following problems. Write your answers in the spaces provided.

Note: Give your answers rounded to the nearest tenth. To make the calculations easier and the answers more consistent, round to the nearest tenth with each calculation.

Assignment Sheet 5

1. An amplifier has an input of 0.3 volts and an output of 9 volts. What is the gain?

____

2. An amplifier puts out a 12-volt signal from a 1.6-volt input. What is the gain?

____

3. An amplifier has an input of 3 watts and an output of 30 watts. What is the gain?

____

4. An amplifier puts out a 65-watt signal from a 10-watt input. What is the gain?

____

5. An amplifier has an input of 20 millivolts and an output of 0.9 volts. What is the gain?

____

6. An amplifier puts out a 18-volt signal from a 0.6-volt input. What is the gain?

____

7. An amplifier has an input of 2.5 watts and an output of 50 watts. What is the gain?

____

8. An amplifier puts out a 1.2-volt signal from a 0.1-volt input. What is the gain?

____

9. An amplifier has an input of 1.3 volts and an output of 39 volts. What is the gain?

____

10. An amplifier puts out a 120-watt signal from a 2.4-watt input. What is the gain?

____

Discrete Semiconductor Devices and Circuits
Unit 1

Assignment Sheet 6—Compute Voltage, Current, and Power Stage Gain in Decibels

Name ______________________________ Overall Rating ____________

Evaluation criteria	**Rating**
• Directions have been followed	________
• Minimum of 80 percent of answers are correct	________
Note: Each correct answer is worth 10 points.	

Introduction: A large segment of the electronics field grew from radio and communications. Consequently, some of the terms and the practices used in various fields of electronics started with the communications specialty. An example of this is the measure of gain. Gain, especially power gain, is sometimes expressed in *decibels.* The bel—named after Alexander Graham Bell—is equal to a gain of 10. Thus, the power gain just calculated can be expressed as 1 bel or 1 B. In general practice, power gain (and loss) is expressed in tenths of a bel or *decibels* (dBs). Bels and decibels are logarithmic expressions of gain. The formula for power gain in decibels is

$$A_P = 10 \times \log_{10} \frac{P_{out}}{P_{in}}$$

Logarithms may seem like a lot to tackle, but to understand decibels you only need to be familiar with a very few logarithmic principles because the formula contains only a base 10 log, the so-called *common logarithms.* To find the number that is equivalent to the $\log_{10}$ of a number, you simply need to look that number up in a logarithm table or use a scientific calculator to convert the number to its logarithm.

Let's look at an example. The input signal on an amplifier is 0.5 watt, while the output is 16 watts. The gain in decibels would be

$$A_P = 10 \times \log_{10} \frac{P_{out}}{P_{in}} = 10 \times \log_{10} \frac{16\text{ W}}{0.5\text{ W}} = 10 \times \log_{10} 32$$

According to the logarithm tables or a scientific calculator, the common log of 32 is 1.5. Thus, in our example, the gain of the amplifier would be 15 dB (10 x 1.5).

Assignment Sheet 6

Gain can also be calculated in decibels using voltage or current. The formulas for these calculations are

$$A_V = 20 \times \log_{10} \frac{V_{out}}{V_{in}}$$

$$A_I = 20 \times \log_{10} \frac{I_{out}}{I_{in}}$$

Note that in these formulas, the log is multiplied by 20 rather than 10. This is to account for the fact that under Watt's Law current and voltage are squared to determine power compared to resistance.

Directions: Use the equations presented to determine the gain in decibels. Write your answers in the spaces provided.

Note: Give your answers rounded to the nearest tenth. To make the calculations easier and the answers more consistent, round to the nearest tenth with each calculation.

1. An amplifier has an input of 0.3 volts and an output of 18 volts. What is the gain?

   ____

2. An amplifier puts out a 12-volt signal from a 1.2-volt input. What is the gain?

   ____

3. An amplifier has an input of 3.6 watts and an output of 30 watts. What is the gain?

   ____

4. An amplifier puts out a 60-watt signal from a 12-watt input. What is the gain?

   ____

5. An amplifier has an input of 40 milliamps and an output of 0.2 amps. What is the gain?

   ____

6. An amplifier puts out a 28-volt signal from a 0.7-volt input. What is the gain?

   ____

7. An amplifier has an input of 2.4 watts and an output of 48 watts. What is the gain?

   ____

Assignment Sheet 6

8. An amplifier puts out a 1.2-amp signal from a 0.2-amp input. What is the gain?

____

9. An amplifier has an input of 0.3 amps and an output of 24 amps. What is the gain?

____

10. An amplifier has a maximum output of 120 watts and a gain rating of 10 dB. What wattage of input signal is required to drive the amplifier to its full power rating?

____

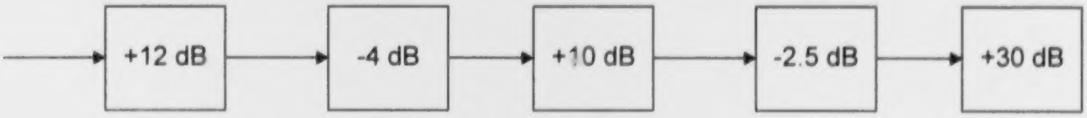
Discrete Semiconductor Devices and Circuits
Unit 1

Assignment Sheet 7—Calculate the Overall Gain of Multistage Amplifiers

Name ______________________________ Overall Rating ____________

Evaluation criteria	**Rating**
• Directions have been followed	________
• Minimum of 80 percent of answers are correct	________
Note: Each correct answer is worth 10 points.	

Introduction: In electronic circuits, amplifiers are often coupled together. This may be done for any of various reasons, such as providing increased gain without having to power a very large amplifier or including amplifiers that are more efficient in changing another signal characteristic—impedance, for example. These amplifier circuits may also include other devices that reduce gain, such as filters and signal detectors, so that additional amplifiers are required to restore lost gain, especially prior to final output. This is one reason that the use of decibels has become popular in expressing gain as opposed to expressing gain in ratios of voltage, amps, or watts. An example should help make this clear. Look at the circuit below. Notice that the devices shown represent changes in decibel gain, some losses as shown by the negative signs and some actual gains. To calculate the overall gain in the circuit, the technician simply needs to add and subtract. The result is an overall gain of 45.5 decibels for the circuit.



$$12 - 4 + 10 - 2.5 + 30 = 45.5$$

Now let's consider the same circuit using gain ratios. A 12 dB gain represents a power gain ratio of

$$12 \text{ dB} = 10 \times \log_{10} \frac{P_{out}}{P_{in}}$$

$$1.2 \text{ dB} = \log_{10} \frac{P_{out}}{P_{in}} = 15.8$$

Assignment Sheet 7

Applying the same formula, the other gain and loss ratios in the circuit equal -2.5, 10, 1.8, and 1000. To use these values to calculate the overall gain ratio of the circuit, we have to multiply by the gains and divide by the losses. The resulting equation for the circuit would be

$$\text{Overall gain ratio} = 15.8 \div 2.5 \times 10 \div 1.8 \times 1000$$

$$= 35{,}111.1$$

We can verify that the two methods are equivalent by substituting the ratio number for the decibel number.

$$\text{Overall gain} = 10 \times \log_{10} \frac{P_{out}}{P_{in}}$$

$$= 10 \times \log_{10} 35{,}111.1$$

$$= 10 \times 4.55$$

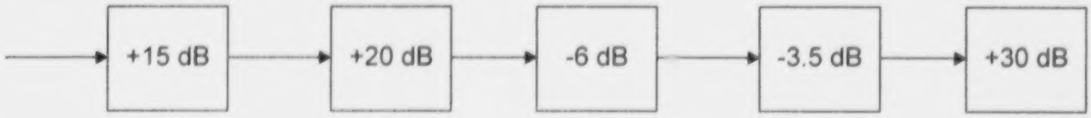
$$= 45.5 \text{ dB}$$

The results are the same, but the decibel numbers and the addition and subtraction operations are generally easier to work with.

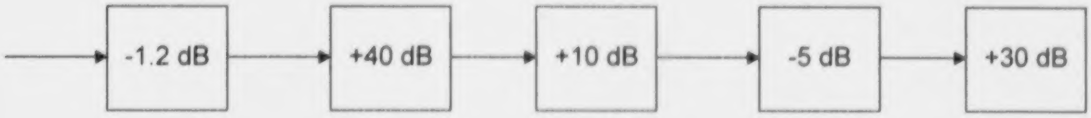
Directions: Calculate the overall gain for the following circuits. Give your answer in decibels or in gain ratio as requested with each problem. Write your answers in the spaces provided.

Note: Give your answers rounded to the nearest tenth. To make the calculations easier and the answers more consistent, round to the nearest tenth with each calculation.

1. Overall gain in decibels: ______________

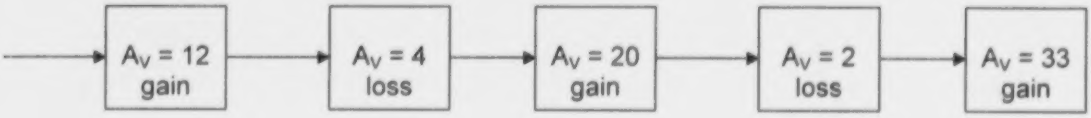


2. Overall gain in decibels: ______________

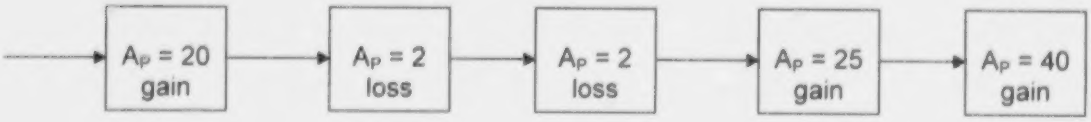


Assignment Sheet 7

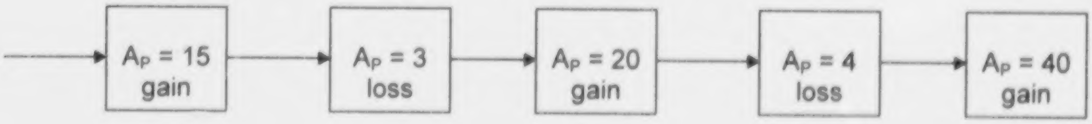
3. Overall gain as ratio gain: ________________


$A_V = 12$ gain
$A_V = 4$ loss
$A_V = 20$ gain
$A_V = 2$ loss
$A_V = 33$ gain

4. Overall gain as ratio gain: ________________


$A_P = 20$ gain
$A_P = 2$ loss
$A_P = 2$ loss
$A_P = 25$ gain
$A_P = 40$ gain

5. Overall gain in decibels: ________________


$A_P = 15$ gain
$A_P = 3$ loss
$A_P = 20$ gain
$A_P = 4$ loss
$A_P = 40$ gain

Discrete Semiconductor Devices and Circuits
Unit 1

Assignment Sheet 8—Identify Types of Transistors Used in Oscillators

Name ______________________________ Overall Rating ____________

Evaluation criteria	**Rating**
• Directions have been followed	________
• Minimum of 82 percent of answers are correct	________
Note: Each correct answer is worth 6 points.	

Introduction: Transistors have a wide variety of uses in electronic circuits. Circuit designers select a particular transistor or type of transistor based on specific desired characteristics for a particular application or, in some cases, to avoid characteristics of other transistors. Even certain standard circuits, such as common oscillators, can often be constructed with any one of several types of transistors. Technicians generally are not responsible for selecting transistors for use in a circuit. But their work does require them to recognize what kind of transistor is used in a specific circuit in order to evaluate its operation or to replace it. This assignment sheet asks you to identify certain types of oscillator circuits and the transistors used in them.

Directions: Study the circuits below and determine whether the circuit uses:

a. NPN bipolar transistors

b. PNP bipolar transistors

c. N-type FET

d. P-type FET

e. Insulated gate FET

f. Unijunction transistors

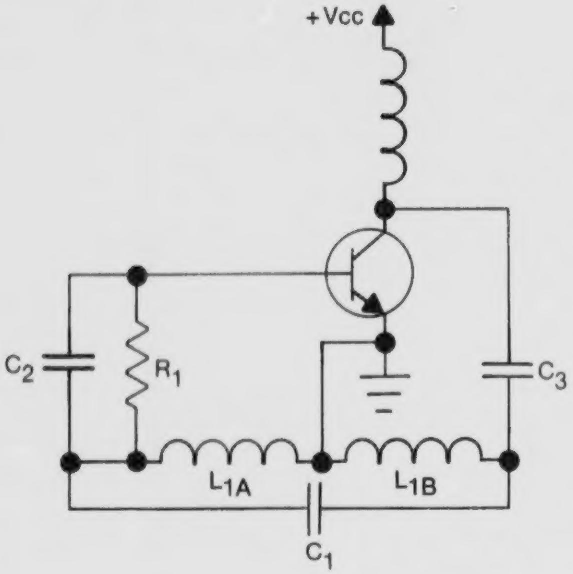
g. A combination of these transistors

Answer the questions that follow the schematics. Write your answers in the spaces provided.

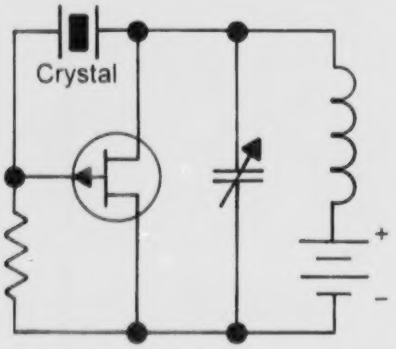
Note: The schematics and questions begin on the next page.

Assignment Sheet 8

1. Type of transistor: ______________


+Vcc
C_2
R_1
C_3
L_{1A}
L_{1B}
C_1

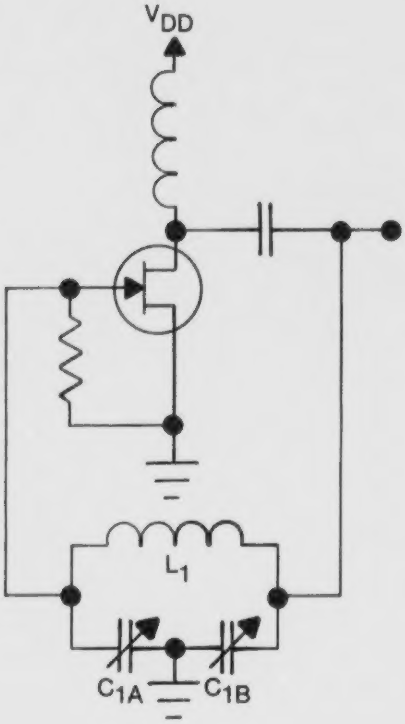
2. Type of transistor: ______________



407

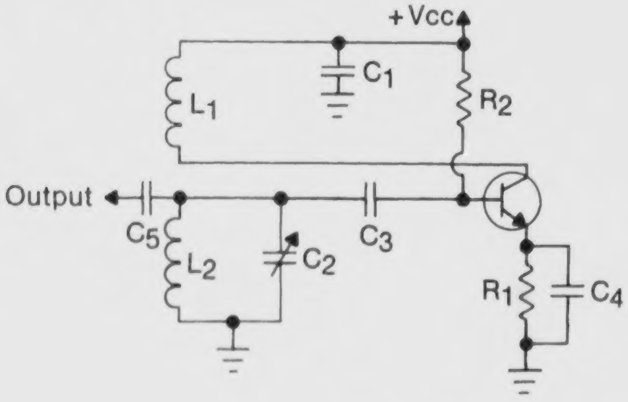
Assignment Sheet 8

3. Type of transistor: ________________



V_{DD}
L_1
C_{1A}
C_{1B}

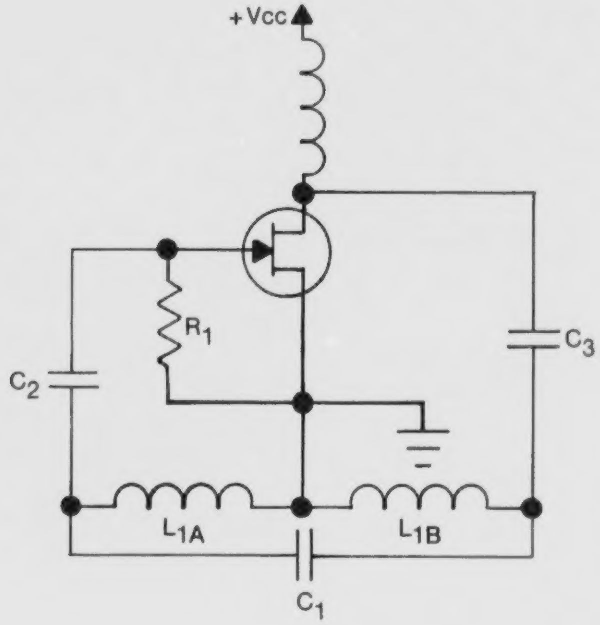
4. Type of transistor: ________________



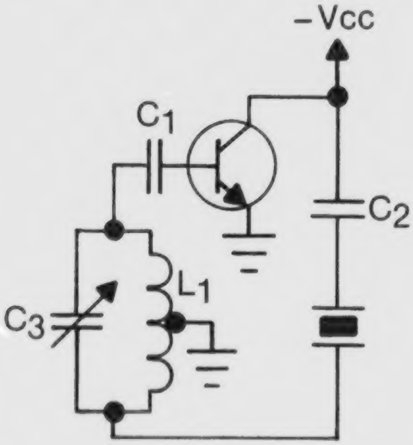
+Vcc
L_1
C_1
R_2
Output
C_5
L_2
C_2
C_3
R_1
C_4

Assignment Sheet 8

5. Type of transistor: ________________


+Vcc
R1
C2
C3
L1A
L1B
C1

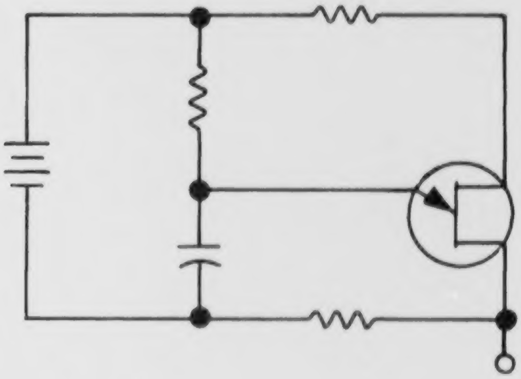
6. Type of transistor: ________________


−Vcc
C1
C2
L1
C3

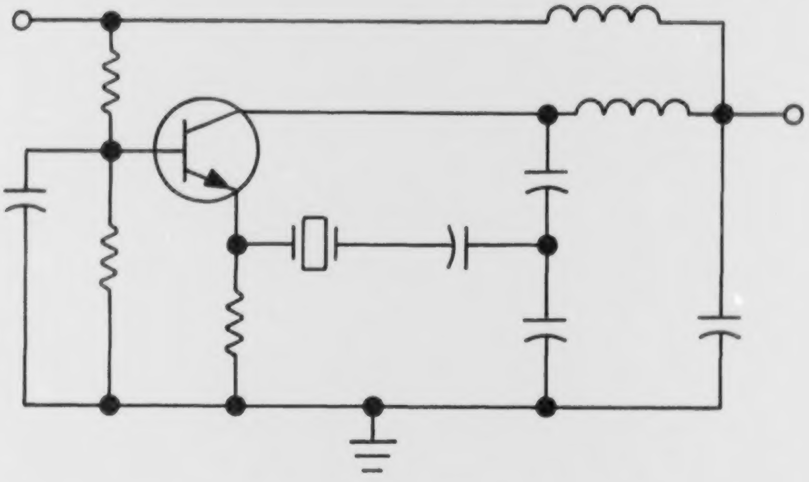
409

Assignment Sheet 8

7. Type of transistor: ________________

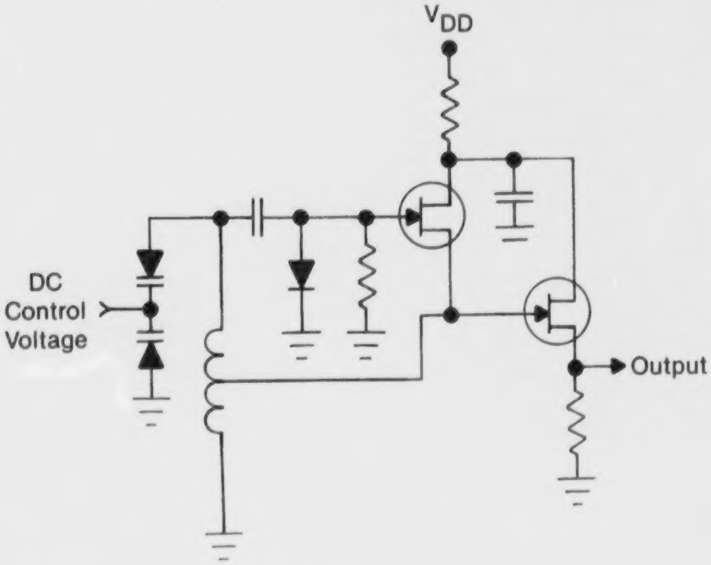


8. Type of transistor: ________________

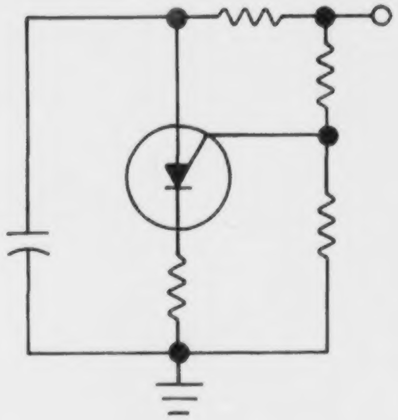


Assignment Sheet 8

9. Type of transistors: ________________

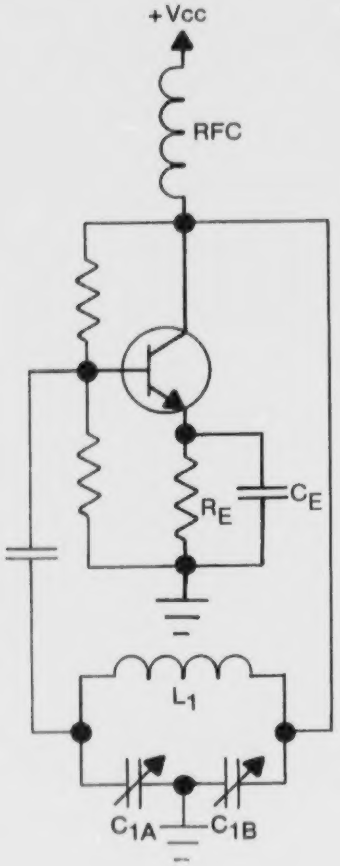

V$_{DD}$
DC Control Voltage
Output

10. Type of transistor: ________________

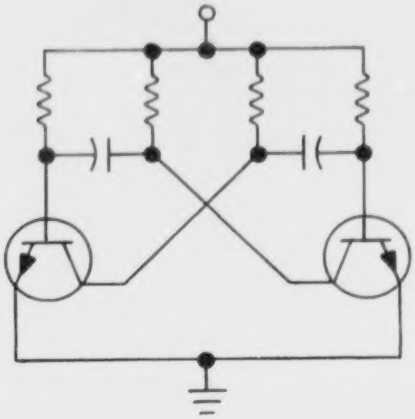


Assignment Sheet 8

11. Type of transistor: ________________


+Vcc
RFC
R_E
C_E
L_1
C_{1A}
C_{1B}

12. Type of transistors: ________________



Assignment Sheet 8

13. Identify the circuits by problem number that show Hartley oscillators.

____

14. Identify the circuits by problem number that show Colpitts oscillators.

____

15. Identify the circuits by problem number that show Armstrong oscillators.

____

16. Identify the circuits by problem number that show crystal-controlled oscillators.

____

Discrete Semiconductor Devices and Circuits
Unit 1

Job Sheet 1— Perform a Static Test of Semiconductor Diodes

Name ________________________ Attempt Number ____________

Date ________________________ Overall Rating ____________

Evaluation criteria	Rating
• Procedure was done correctly	________
• Equipment was used correctly	________
• Diode status was correctly identified	________

Introduction: The basic semiconductor device is the diode. Its primary purpose is to rectify alternating current to produce DC. But the characteristic that makes a bipolar diode so good as a rectifier also makes it useful in other applications. For example, it allows current flow in one direction only. These two basic functions are the principal factors to be tested on a diode. First, you should verify the polarity of the diode. Then you should check to see that there is current flow in one direction and one direction only. This job sheet presents the basic procedure for making those tests.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Two multimeters or a voltmeter and an ohmmeter
- Test leads
- Diodes provided by instructor
- Pencil and paper
- Masking tape

B. Procedure

☐ 1. Determine the polarity of the ohmmeter leads by connecting them to a voltmeter.

☐ 2. Mark the polarity of the ohmmeter leads with masking tape.

Job Sheet 1

☐ 3. Set the ohmmeter to the R x 100 scale.

☐ 4. Connect the positive lead of the ohmmeter to the anode of the diode and the negative lead to the cathode.

Note: If you are uncertain as to which lead is which and cannot determine the anode and cathode from available resources, choose one lead to try as the anode and the other to try as the cathode.

☐ 5. Record the ohmmeter reading as the *forward-biased resistance* value for that diode.

☐ 6. Reverse the ohmmeter connections on the diode.

☐ 7. Record the ohmmeter reading as the *reverse-biased resistance* for that diode.

☐ 8. Accept or reject the diode based on a low ohmic reading for forward-biasing and a very high ohmic reading for reverse biasing.

☐ 9. Repeat Steps 4-8 for the remaining diodes.

☐ 10. Return equipment and materials to their proper storage location.

Evaluator's comments: ____

____

____

____

Discrete Semiconductor Devices and Circuits
Unit 1

Job Sheet 2— Test a Semiconductor Diode and Plot Characteristic Curves

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedures were done correctly	________
• Equipment was used correctly	________
• Circuit was correctly assembled	________
• Measurements were accurate	________
• Student demonstrated an understanding of the applicable principles	________

Introduction: In this unit you have seen how helpful characteristic curve graphs can be in analyzing the performance of semiconductor devices such as transistors. Similar graphs can be made for other devices, including diodes. The graphs are created through the testing of many samples of actual devices to describe average performance. In this job sheet, you will test a diode and create a characteristic curve for it.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

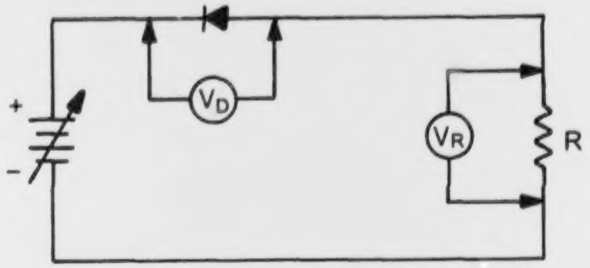
- Two multimeters
- Test leads
- Variable DC power supply (0 to 30 volts)
- 220-ohm resistor, 5 watts

Note: The diode must have a peak inverse voltage of at least 25 volts.

- Conductor
- Mounting surface and hardware
- Pencil and paper
- Graph paper
- Table at end of job sheet

Job Sheet 2

- Circuit drawing



B. Procedure

☐ 1. Configure the multimeters to operate as voltmeters.

☐ 2. Assemble circuit per drawing, but do **not** apply power.

☐ 3. Check the polarity of the circuit to ensure proper connections.

Note: The negative lead of the power supply should be connected to the anode of the diode.

☐ 4. Set the power supply to 0 volts.

☐ 5. Apply power.

☐ 6. Record the voltage reading across the resistor in the table under **0 V** for **Reverse-Biased**.

☐ 7. Record the voltage reading across the diode in the table under **0 V** for **Reverse-Biased**.

☐ 8. Increase the power supply to 1 volt.

☐ 9. Repeat Steps 6 and 7 for 1 volt.

☐ 10. Repeat Steps 8 and 9 for the remaining voltages in the table.

☐ 11. Remove power from the circuit.

☐ 12. Remove the diode and replace it so the negative terminal of the power supply is connected to the cathode.

☐ 13. Repeat Steps 4-11 for this configuration, recording your readings for **Forward-Biased**.

Job Sheet 2

☐ 14. Calculate the current value for each voltage setting and record the values in the table.

☐ 15. Prepare a graph with the horizontal axis being the diode voltage and the vertical axis being the diode current.

☐ 16. Plot the forward- and reverse-biased curves on the graph.

☐ 17. Discuss your results with your instructor.

☐ 18. Return equipment and materials to their proper storage location.

Evaluator's comments: ____

____

____

____

Job Sheet 2

Data Sheet

Table 1—Reverse Biasing Readings

Power Supply	0 V	1 V	2 V	3 V	4 V	5V	10 V	15 V	20 V	25 V
Diode Voltage										
Resistor Voltage										
Current (amps)										

Table 2—Forward Biasing Readings

Power Supply	0 V	0.1 V	0.2 V	0.3 V	0.4 V	0.5 V	0.6 V	0.7 V	0.8 V	0.9 V	1 V	2 V	4 V
Diode Voltage													
Resistor Voltage													
Current (amps)													

Notes:

Discrete Semiconductor Devices and Circuits
Unit 1

Job Sheet 3— Construct and Test a Half-Wave Rectifier Circuit

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedures were done correctly	________
• Equipment was used correctly	________
• Circuit was properly wired	________
• Student demonstrated an understanding of the applicable principles	________

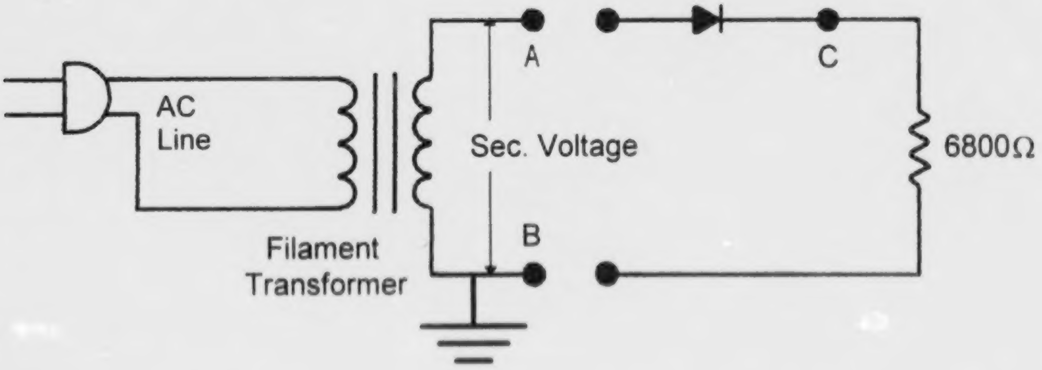
Introduction: Diodes are important in electronics circuits because of their ability to rectify AC power because most pieces of electronic equipment require direct current. But straight rectification of AC is wasteful because so much of the waveform can be lost. Consequently, engineers have devised a number of circuits over the years to improve the rectification process. In this and the next job sheet, you will have an opportunity to build and operate two of the most popular rectifying circuits.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- 120-volt low-power filament transformer
- Multimeter
- Test leads
- Oscilloscope
- Silicon diode, 1N4004 or equivalent
- Two 6.8-Kohm resistors, ¼-watt
- Conductor
- Mounting surface and hardware
- Pencil and paper
- Graph paper
- Circuit drawing on next page

Job Sheet 3



B. Procedure

☐ 1. Set the multimeter to measure AC voltage.

☐ 2. Turn on the filament transformer and measure the output of the secondary terminals.

☐ 3. Turn off power.

☐ 4. Assemble circuit per drawing, but do **not** apply power.

Caution: This procedure involves dangerous voltages. Review safety procedures and have your instructor verify your circuit before continuing.

☐ 5. Apply power to the circuit.

☐ 6. Measure the voltage between Points A and B and record as the AC input voltage.

☐ 7. Change the multimeter to read DC voltage.

☐ 8. Measure the voltage between Points B and C and record as the DC output voltage.

☐ 9. Use the graph paper to make a scale drawing of the AC input voltage and the DC output voltage.

☐ 10. Calculate the average DC output voltage and compare it to the measured DC output voltage.

Job Sheet 3

☐ 11. Discuss the results with your instructor.

☐ 12. Disassemble circuit and return equipment and materials to their proper storage location.

Evaluator's comments: ______________________________

____

____

____

Discrete Semiconductor Devices and Circuits
Unit 1

Job Sheet 4— Construct and Test a Full-Wave Bridge Rectifier Circuit

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	Rating
• Procedures were done correctly	________
• Equipment was used correctly	________
• Circuit was properly wired	________
• Student demonstrated an understanding of the applicable principles	________

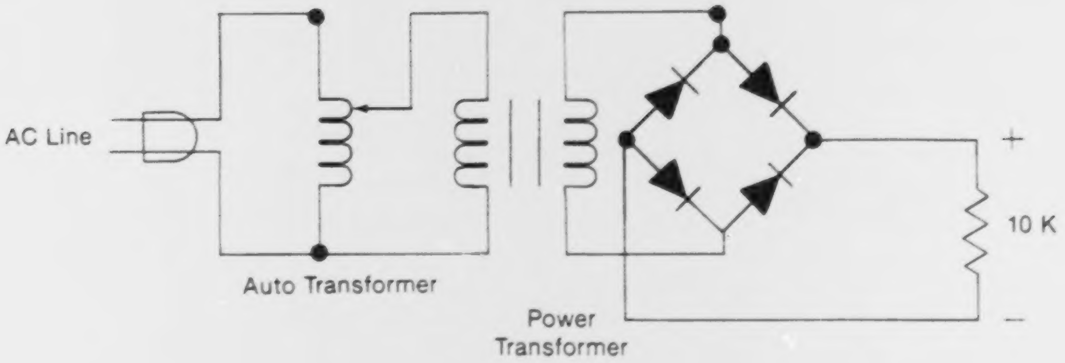
Introduction: The advantage of a full-wave rectifier over a half-wave rectifier is that the former provides power across the full 360° of the waveform cycle. Its disadvantage is that the circuit is more complex. This job sheet compared to Job Sheet 3 will give you an idea of the differences between the two circuits.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Autotransformer (0-130 volts)
- Power transformer (110-220 volts, center-tapped)
- Four silicon diodes, 1N4004 or equivalent
- 10 Kohm resistor, 1-watt
- Multimeter
- Oscilloscope
- Test leads
- Paper and pencil
- Graph paper
- Circuit drawing on the next page

Job Sheet 4



B Procedure

☐ 1 Assemble the circuit per drawing, but do **not** apply power.

☐ 2. Have your instructor check the circuit.

☐ 3. Connect the multimeter across the secondary of the power transformer.

☐ 4. Plug the autotransformer into the AC circuit and adjust for a reading of 10 volts on the multimeter.

☐ 5. Adjust the multimeter to read DC voltage.

☐ 6. Measure and record the DC voltage across the load resistor.

☐ 7. Connect the oscilloscope across the power transformer and adjust for a stable waveform.

☐ 8. Sketch the waveform, noting its values.

☐ 9. Connect the oscilloscope across the load resistor and adjust for a stable waveform.

☐ 10. Sketch the waveform.

☐ 11. Calculate the average DC output voltage and compare your calculation to the measured voltage.

☐ 12. Discuss your results with your instructor.

☐ 13. Disassemble circuit and return equipment and materials to their proper storage location.

Job Sheet 4

Evaluator's comments:

Discrete Semiconductor Devices and Circuits
Unit 1

Job Sheet 5— Test and Replace Light-Sensitive Devices

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation criteria	**Rating**
• Procedures were done correctly	________
• Equipment was properly connected and operated	________
• Measurements were accurate	________

Introduction: There are numerous types of light-sensitive devices, such as photodiodes, phototransistors, and others. With the increasing usage of fiber optic networks, light-sensitive devices will continue to play an important role in the electronics industry. Basically, such devices have the same principle of operation: when struck by light, they produce a current. The nature of the current, its on and off points, the type of light required, and other factors will vary for particular devices, but even so the basic principle is pretty much the same. Thus, you should be able to figure out that testing such devices requires that they be exposed to light and check for production of a current. The details of testing photo-sensitive devices will vary with the component and with the requirements for precision measurements, but this job sheet presents a helpful yet basic approach to testing light-sensitive components.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Multimeter
- Test leads
- Cadmium sulfide photocell or similar light-sensitive device

B. Procedure

☐ 1. Determine polarity of meter leads.

☐ 2. Set multimeter as an ohmmeter to measure on the R x 1Kohm scale.

☐ 3. Connect the meter leads to the device, observing polarity as required.

Job Sheet 5

☐ 4. Ensure that the device's light window is exposed to a light source.

☐ 5. Measure and record ohmmeter reading.

☐ 6. Cover the window of the device to prevent light from entering it.

☐ 7. Measure and record ohmmeter reading.

☐ 8. Reject device if ohmmeter readings are not different.

☐ 9. Return equipment and materials to their proper storage area.

Evaluator's comments: ______________________________

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Discrete Semiconductor Devices and Circuits
Unit 1

Job Sheet 6— Test Transistors

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	Rating
• Procedures were done correctly	________
• Equipment was properly connected and operated	________
• Measurements were accurate	________
• Student demonstrated an understanding of the applicable principles	________

Introduction: The invention of the transistor marks the real beginning of the modern electronics era. In its many variations, transistors are still one of the most important discrete devices in use today and they are the basis by which integrated devices are measured. Certainly, an electronics technician must be able to verify the operation of transistors. The task is so important that some shops have test equipment specifically designed to test transistors. In this job sheet, you will test a variety of transistors to determine whether they are operational.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Multimeter, ohmmeter, or transistor tester
- Test leads
- Assortment of transistors provided by instructor
- Four component trays marked *Good NPN*, *Good PNP*, *Shorted*, and *Open* respectively
- Pencil and paper

B. Procedure

☐ 1. Determine polarity of meter leads.

☐ 2. Set test equipment for testing, such as setting up the multimeter as an ohmmeter on the R x 100 range.

☐ 3. Select a transistor for testing.

Job Sheet 6

☐ 4. Identify the leads on the transistor.

Examples: Base, collector, emitter, drain, source

☐ 5. Place the positive ohmmeter lead on the transistor emitter lead and the negative ohmmeter lead on the base lead.

☐ 6. Measure and record the resistance reading.

☐ 7. Place the negative ohmmeter lead on the transistor emitter lead and the positive ohmmeter lead on the base lead.

☐ 8. Measure and record the resistance reading.

☐ 9. Compare the two resistance readings.

☐ 10. Repeat Steps 5-9 for the collector and base leads.

☐ 11. Place the transistor in the appropriate component tray based on the test results.

☐ 12. Repeat Steps 5-11 for the remaining transistors.

☐ 13. Discuss your results with your instructor.

☐ 14. Return equipment and materials to their proper storage location.

Evaluator's comments: ____

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Discrete Semiconductor Devices and Circuits
Unit 1

Job Sheet 7— Construct and Test a Common-Emitter Circuit

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedures were done correctly	________
• Circuit was properly wired	________
• Measurements were accurate	________
• Student demonstrated an understanding of the applicable principles	________

Introduction: To this point in your studies, you have dealt mainly with two-lead devices, such as resistors, capacitors, inductors, and diodes. Most transistors have three or more leads, and other discrete and integrated circuits often have many more. Therefore, it is important for the electronics technician to understand how the different leads of a component affect the device's operation and how they relate to the rest of the circuit. In this series of job sheets, you will build and test different configurations of transistor circuits that use the three bipolar transistor leads in different ways. We will begin with the common-emitter circuit.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

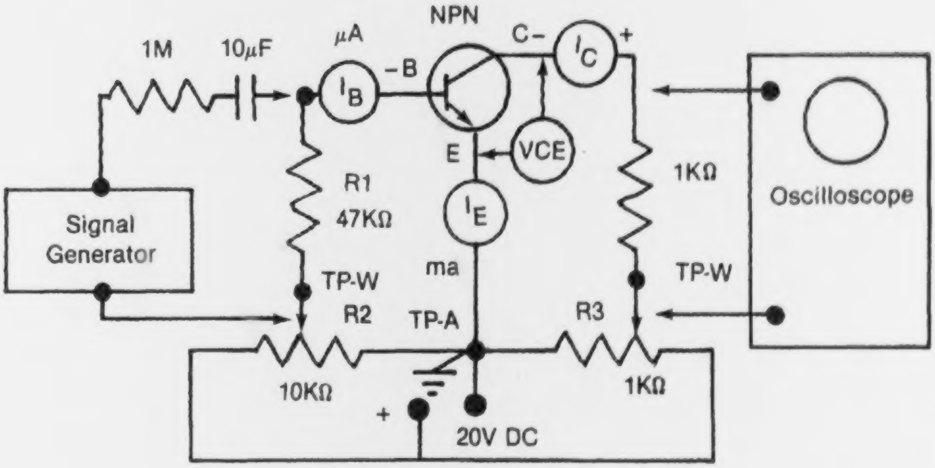
- Multimeter or voltmeter
- Three ammeters (0 to 50 mA range)

  Note: One ammeter needs to be capable of microamp readings for measurements on the base-lead circuit. If such an ammeter is not available, insert a 100-ohm resistor in series with the circuit and use the voltage drop reading to calculate a resistor that will allow the use of the available ammeter.

- Oscilloscope
- Audio signal generator
- Power supply (0 to 20 VDC)
- Test leads
- NPN transistor

Job Sheet 7

- 1 Mohm resistor, ½-watt
- 47 Kohm resistor, ½-watt
- 1 Kohm resistor, ½-watt
- 10 Kohm resistor, ½-watt
- 1 Kohm potentiometer
- 10 Kohm potentiometer
- 10 µF capacitor
- Low-voltage conductor
- Mounting surface and hardware
- Pencil and paper
- Table at end of job sheet
- Circuit drawing


NPN
1M
10μF
μA
C –
+
I_C
– B
I_B
E
VCE
1KΩ
Oscilloscope
R1
47KΩ
I_E
Signal Generator
TP-W
ma
TP-W
R2
TP-A
R3
10KΩ
1KΩ
+
20V DC

B. Procedure

☐ 1. Assemble the circuit per drawing, but do **not** apply power.

☐ 2. Have your instructor check your circuit.

☐ 3. Set the 10 Kohm potentiometer to 0 ohms between Test Points A and W.

☐ 4. Set the power supply to 20 VDC.

☐ 5. Adjust the 1 Kohm potentiometer until V_{CE} is 6.0 volts.

☐ 6. Adjust the 10 Kohm potentiometer until the base current (I_B) is 20 µA.

Job Sheet 7

☐ 7. Recheck the 1 Kohm potentiometer and adjust as necessary to achieve 6 volts.

Note: It may be necessary to make minor adjustments to balance the potentiometers to obtain the required readings. If you are unable to achieve the proper settings, check with your instructor.

☐ 8. Check and record I_C.

☐ 9. Connect the voltmeter to read the base-emitter DC voltage.

☐ 10. Increase the 10 Kohm potentiometer until I_B is 40 μA.

☐ 11. Adjust the potentiometers as necessary to obtain 40 μA and 6 V.

☐ 12. Check and record I_C.

☐ 13. Connect the signal generator to the 47 Kohm resistor and set the output frequency to 1 KHz.

☐ 14. Turn on the signal generator and adjust the input signal (E_{in}) to 10 mV rms.

☐ 15. Use the oscilloscope to view the waveform and make a sketch of it showing amplitude and frequency.

☐ 16. Reconnect the oscilloscope to observe the voltage across the 1 Kohm output resistor.

☐ 17. Make a sketch of this waveform, showing amplitude and frequency.

☐ 18. Compute and record the output voltage (E_{out}) in rms.

☐ 19. Compute the output current (I_{out}) by dividing the output voltage by the load resistance.

☐ 20. Measure the rms voltage across the 1 Mohm resistor.

☐ 21. Compute and record the input current (I_{in}).

☐ 22. Calculate the current gain by dividing I_{out} by I_{in} and express the value in decibels.

☐ 23. Remove power from the circuit.

☐ 24. Discuss your results with your instructor.

☐ 25. Return equipment and materials to their proper storage location.

Evaluator's comments:

Job Sheet 7

Table 1—DC Measurements

	I_E	I_B	I_C	V_{BE}
V_{CE} = 6 V		20 μA		
V_{CE} = 6 V		40 μA		
A_I =				

Table 2—AC Measurements

	P-P	rms
V_{in}		
I_{in} (calculated)		
V_{out}		
I_{out}		
A_I (decibels)		

Discrete Semiconductor Devices and Circuits
Unit 1

Job Sheet 8— Construct and Test a Common-Base Circuit

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedures were done correctly	________
• Circuit was properly wired	________
• Measurements were accurate	________
• Student demonstrated an understanding of the applicable principles	________

Introduction: In Job Sheet 7, you worked with a common-emitter circuit. In this job sheet, the circuit will change to a common-base circuit and you will use a PNP transistor. Based on what you already know about the functioning of transistors and the common-base configuration, anticipate the changes you might expect to see when doing tests similar to those in the previous job sheet.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

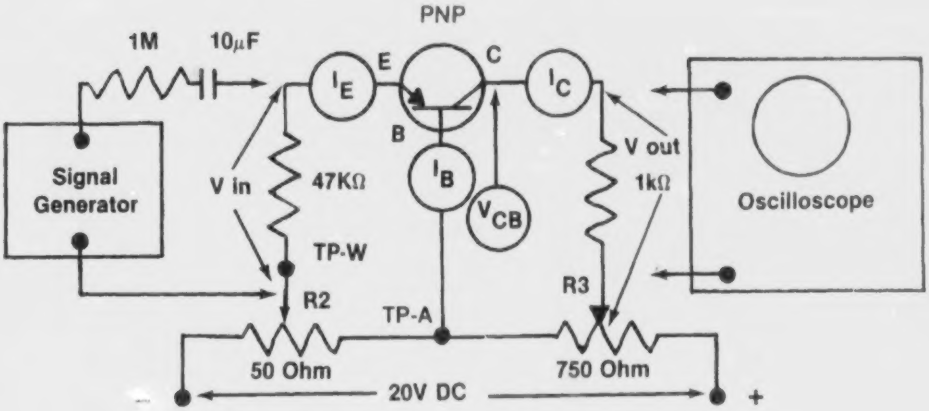
- Multimeter or voltmeter
- Three ammeters (0 to 50 mA range)

  Note: One ammeter needs to be capable of microamp readings for measurements on the base-lead circuit. If such an ammeter is not available, insert a 100-ohm resistor in series with the circuit and use the voltage drop reading to calculate a resistor that will allow the use of the available ammeter.

- Oscilloscope
- Audio signal generator
- Power supply (0 to 20 VDC)
- Test leads
- PNP transistor
- 1 Mohm resistor, ½-watt
- 47 Kohm resistor, ½-watt

Job Sheet 8

- 1 Kohm resistor, ½-watt
- 10 Kohm resistor, ½-watt
- 50 ohm potentiometer, 1-watt
- 750 ohm potentiometer, 1-watt
- 10 µF capacitor
- Low-voltage conductor
- Mounting surface and hardware
- Pencil and paper
- Table at end of job sheet
- Circuit drawing


PNP
1M
10µF
E
C
B
I_E
I_C
I_B
V_{CB}
Signal Generator
V in
47KΩ
TP-W
R2
TP-A
V out
1kΩ
R3
Oscilloscope
50 Ohm
750 Ohm
–
20V DC
+

B. Procedure

☐ 1. Assemble the circuit per drawing, but do **not** apply power.

☐ 2. Have your instructor check your circuit.

☐ 3. Set the potentiometer to 0 ohms between Test Points A and W.

☐ 4. Set the power supply to 20 VDC.

☐ 5. Adjust the 750 ohm potentiometer until V_{CB} is 5.8 volts.

☐ 6. Adjust the 50 ohm potentiometer until the collector current (I_C) is 25 mA.

☐ 7. Check and record I_C, I_B, and I_E.

☐ 8. Adjust the 50 ohm potentiometer to obtain a 20 µA increase in I_B.

Job Sheet 8

☐ 9. Recheck the 750 ohm potentiometer and adjust as necessary to achieve 5.8 volts.

Note: It may be necessary to make minor adjustments to balance the potentiometers to obtain the required readings. If you are unable to achieve the proper settings, check with your instructor.

☐ 10. Check and record I_C, I_B, and I_E.

☐ 11. Connect the voltmeter to read the emitter-base DC voltage.

☐ 12. Connect the signal generator to the 47 Kohm resistor and set the output frequency to 1 KHz.

☐ 13. Turn on the signal generator.

☐ 14. Use the oscilloscope to view the waveform and make a sketch of it showing amplitude and frequency.

☐ 15. Reconnect the oscilloscope to observe the voltage across the 1 Kohm output resistor.

☐ 16. Make a sketch of this waveform, showing amplitude and frequency.

☐ 17. Compute and record the output voltage (E_{out}) in rms.

☐ 18. Compute the output current (I_{out}) by dividing the output voltage by the load resistance.

☐ 19. Measure the rms voltage across the 1 Mohm resistor.

☐ 20. Compute and record the input current (I_{in}).

☐ 21. Calculate the voltage gain and express the value in decibels.

☐ 22. Remove power from the circuit.

☐ 23. Discuss your results with your instructor.

☐ 24. Return equipment and materials to their proper storage location.

Job Sheet 8

Evaluator's comments: ____________________

Job Sheet 8

Table 1—DC Measurements

V_{CB}	I_C	I_B	I_E	$\frac{\Delta I_C}{\Delta I_B}$
5.8 V	25 mA			
5.8 V				

Table 2—AC Measurements

	P-P	rms
E_{in}		
V_{in}		
E_{out}		
I_{in}		
I_{out}		
A_V (decibels)		

Discrete Semiconductor Devices and Circuits
Unit 1

Job Sheet 9— Construct and Test a Common-Collector Circuit

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating ____________

Evaluation criteria	**Rating**
• Procedures were done correctly	________
• Circuit was properly wired	________
• Measurements were accurate	________
• Student demonstrated an understanding of the applicable principles	________

Introduction: The final common transistor circuit configuration that we will look at is the common-collector circuit. You will conduct the same types of tests that you performed previously on the common-base and common-emitter configurations. Again, try to anticipate the types of changes you may expect to see.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

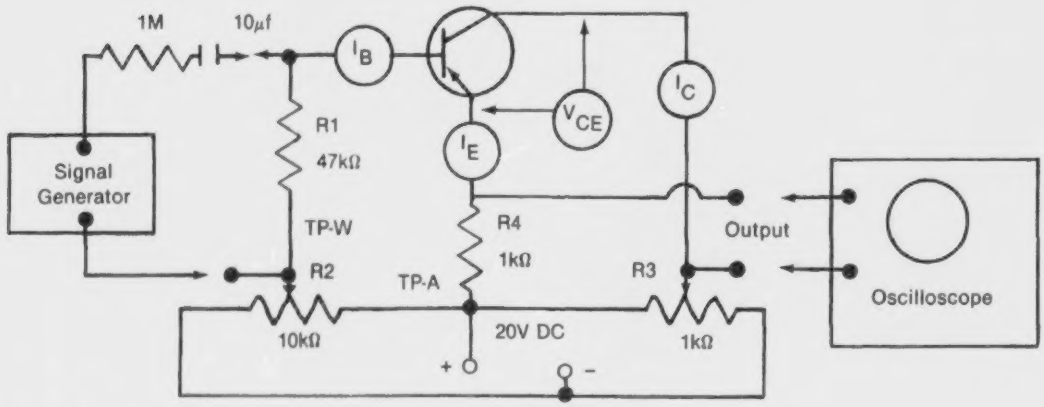
- Multimeter or voltmeter
- Three ammeters (0 to 50 mA range)

  Note: One ammeter needs to be capable of microamp readings for measurements on the base-lead circuit. If such an ammeter is not available, insert a 100-ohm resistor in series with the circuit and use the voltage drop reading to calculate a resistor that will allow the use of the available ammeter.

- Oscilloscope
- Audio signal generator
- Power supply (0 to 20 VDC)
- Test leads
- PNP transistor
- 1 Mohm resistor, ½-watt
- 47 Kohm resistor, ½-watt
- 1 Kohm resistor, ½-watt

Job Sheet 9

- 1 Kohm potentiometer, 1-watt
- 10 Kohm potentiometer, 1-watt
- 10 μF capacitor
- Low-voltage conductor
- Mounting surface and hardware
- Pencil and paper
- Table at end of job sheet
- Circuit drawing


1M
10μf
I_B
I_C
V_{CE}
I_E
R1
47kΩ
Signal Generator
TP-W
R2
TP-A
R4
1kΩ
Output
R3
Oscilloscope
10kΩ
20V DC
1kΩ
+
-

B. Procedure

☐ 1. Assemble the circuit per drawing, but do **not** apply power.

☐ 2. Have your instructor check your circuit.

☐ 3. Set the 10 Kohm potentiometer to 0 ohms between Test Points A and W.

☐ 4. Set the power supply to 20 VDC.

☐ 5. Adjust the 1 Kohm potentiometer until V_{CE} is 6.0 volts.

☐ 6. Adjust the 10 Kohm potentiometer until the base current (I_B) is 20 μA.

☐ 7. Recheck the 1 Kohm potentiometer and adjust as necessary to achieve 6 volts.

Note: It may be necessary to make minor adjustments to balance the potentiometers to obtain the required readings. If you are unable to achieve the proper settings, check with your instructor.

☐ 8. Check and record I_C, I_B, and I_E.

Job Sheet 9

☐ 9. Connect the voltmeter to read the base-emitter DC voltage.

☐ 10. Connect the signal generator to the 47 Kohm resistor and set the output frequency to 1 KHz.

☐ 11. Turn on the signal generator and adjust the input signal (E_{in}) to 10 mV rms.

☐ 12. Use the oscilloscope to view the waveform and make a sketch of it showing amplitude and frequency.

☐ 13. Reconnect the oscilloscope to observe the voltage across the 1 Kohm output resistor.

☐ 14. Make a sketch of this waveform, showing amplitude and frequency.

☐ 15. Compute and record the output voltage (E_{out}) in rms.

☐ 16. Compute the output current (I_{out}) in rms.

☐ 17. Measure the rms voltage across the 1 Mohm resistor.

☐ 18. Compute and record the input current (I_{in}).

☐ 19. Calculate the power gain and express the value in decibels.

☐ 20. Remove power from the circuit.

☐ 21. Discuss your results with your instructor.

☐ 22. Return equipment and materials to their proper storage location.

Evaluator's comments: ______________________________

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Job Sheet 9

Table 1—DC Measurements

V_{CE}	I_E	I_B	I_C	$\frac{\Delta I_C}{\Delta I_B}$
6 V		20 μA		
6 V		40 μA		

Table 2—AC Measurements

	P-P	rms
E_{in}		
E_{out}		
V (1 Kohm)		
V (1 Mohm)		
I_{in}		
I_{out}		
A_V (decibels)		

Discrete Semiconductor Devices and Circuits
Unit 1

Job Sheet 10— Plot a Transistor Output Characteristic Curve

Name ______________________ Attempt Number __________

Date ______________________ Overall Rating __________

Evaluation criteria	Rating
• Procedures were done correctly	______
• Circuit was properly wired	______
• Measurements were accurate	______
• Student demonstrated an understanding of the applicable principles	______

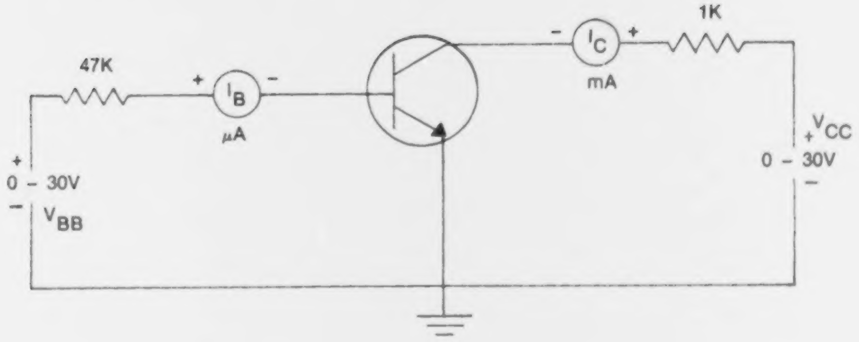
Introduction: Due to the popularity of transistor circuits, their characteristic curves are important tools for technicians and engineers. Previously, you have plotted a characteristic curve for a diode and have used a transistor characteristic curve to plot the load line of a common-emitter circuit (Assignment Sheet 4). Remember, however, that the performance of a device like a transistor is described by a family of curves. In this job sheet, you will perform the tests necessary to create a transistor output characteristic curve.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Multimeter
- Microammeter or suitable multimeter
- Two milliammeters or suitable multimeters
- Test leads
- Two power supplies (0 to 20 VDC)
- NPN transistor
- 1 Kohm resistor
- 47 Kohm resistor
- Low-voltage conductor
- Mounting surface and hardware
- Paper and pencil
- Graph paper
- Table at end of job sheet
- Circuit drawing on the next page

Job Sheet 10



B. Procedure

☐ 1. Assemble the circuit per the drawing, but do **not** apply power.

☐ 2. Have your instructor check your circuit.

Note: This procedure outlines the steps for creating curves for three values of base current. Discuss with your instructor if you need to do additional base current values for this assignment. If additional values are requested, create a table for each additional value similar to those at the end of this job sheet.

☐ 3. Turn on the V_{BB} power supply and adjust it to get an I_B reading of 20 μA.

☐ 4. Record the power supply setting.

☐ 5. Turn on the V_{CC} power supply and adjust it to 0.2 VDC.

Note: It may be necessary to use small voltage clamps for setting below 5 VDC. Discuss this with your instructor.

☐ 6. Record the reading on the table for I_B = 20 μA.

☐ 7. Adjust the V_{CC} power supply to 0.4 VDC.

☐ 8. Record the reading on the table for I_B = 20 μA.

☐ 9. Repeat Steps 7 and 8 for the remaining settings on the table for I_B = 20 μA.

☐ 10. Adjust the V_{CC} power supply to 0 VDC.

☐ 11. Adjust the V_{BB} power supply to get an I_B reading of 40 μA.

Job Sheet 10

☐ 12. Record this value.

☐ 13. Repeat Steps 7 and 8 for each setting on the table, recording the values for $I_B = 40\ \mu A$.

☐ 14. Adjust the V_{CC} power supply to 0 VDC.

☐ 15. Adjust the V_{BB} power supply to get an I_B reading of 60 μA.

☐ 16. Record this value.

☐ 17. Adjust the V_{CC} power supply to 0 VDC.

☐ 18. Adjust the V_{BB} power supply to get an I_B reading of 60 μA.

☐ 19. Record this value.

☐ 20. Repeat Steps 7 and 8 for each setting on the table, recording the values for $I_B = 60\ \mu A$.

☐ 21. Adjust the V_{CC} power supply to 0 VDC.

☐ 22. Repeat Steps 18-21 for any additional values of I_B requested by your instructor at Step 2.

☐ 23. Remove power from the circuit.

☐ 24. Use the graph paper to create a characteristic curve based on the values that you have recorded, with V_{CC} on the horizontal axis, I_C in milliamps on the vertical axis, and a plotted curve for each value of I_B.

☐ 25. Discuss your results with your instructor.

☐ 26. Disassemble the circuit and return equipment and materials to their proper storage location.

Evaluator's comments: ______________________________

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Job Sheet 10

Table 1—Values for I_C

I_B	V_{CC}												
	0.2	0.4	0.6	0.8	1.0	1.5	2.0	2.5	3.0	5.0	7.5	10.0	15.0
20 µA													
40 µA													
60 µA													

Discrete Semiconductor Devices and Circuits
Unit 1

Job Sheet 11— Construct and Test a Single-Ended Amplifier

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	Rating
• Equipment was set up correctly	________
• Correct procedures were followed	________
• Circuit was correctly wired	________
• Student demonstrated an understanding of the applicable principles	________

Introduction: One of the advantages of using discrete semiconductor components over vacuum tubes and other devices is that the components can operate on such low power levels. However, to make this practical, semiconductor circuitry requires extensive use of amplifiers. A number of job sheets in this unit and the next will allow you to practice using many of the types of amplifiers that are commonly used in today's electronic equipment. We will begin with a transistor-based, single-ended amplifier.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

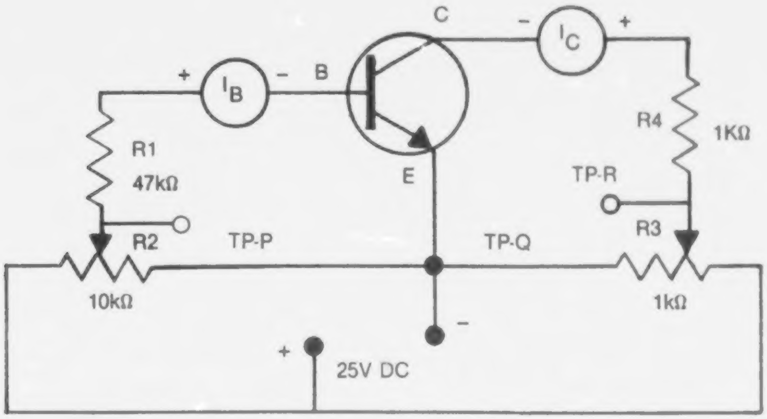
A. Equipment and materials

- Microammeter or multimeter
- Milliammeter or multimeter
- DC power supply, 0-25 volts
- Test leads
- Heat source (such as soldering iron or gun or heat gun)
- NPN transistor
- 47 Kohm resistor, ½-watt
- 1 Kohm resistor, ½-watt
- 22 Kohm resistor, ½-watt
- 220 Kohm resistor, ½-watt
- 1.5 Kohm resistor, ½-watt
- 4.7 Kohm resistor, ½-watt
- 1 Kohm potentiometer
- 10 Kohm potentiometer

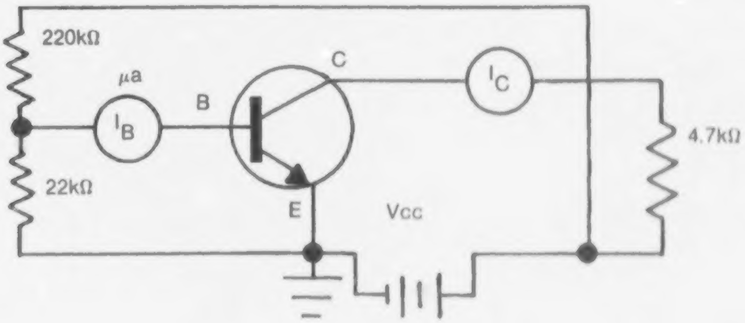
Job Sheet 11

- Low-voltage conductor
- Mounting surface and hardware
- Pencil and paper
- Tables at end of job sheet
- Circuit drawings

Circuit 1 Schematic


C
- I_C +
+ I_B − B
R4
1KΩ
R1
47kΩ
E
TP-R
R2
TP-P
TP-Q
R3
10kΩ
1kΩ
−
+
25V DC

Circuit 2 Schematic


220kΩ
μa
C
I_C
B
I_B
4.7kΩ
22kΩ
E
Vcc

B Procedure

☐ 1. Assemble circuit per Circuit 1 Schematic, but do **not** apply power.

☐ 2. Adjust the 10 Kohm potentiometer so that the voltage between Test Points P and Q will be 0.

Job Sheet 11

- ☐ 3. If required, energize the heat source to allow it to warm up.
- ☐ 4. Have your instructor check your circuit.
- ☐ 5. Set power supply to 25 VDC and energize the circuit.
- ☐ 6. Adjust the 1 Kohm potentiometer for 18 volts between Test Points Q and R.
- ☐ 7. Adjust the 10 Kohm potentiometer for an I_B of 50 μA.
- ☐ 8. Record the value of I_C.
- ☐ 9. Hold the heat source near but not touching the transistor for approximately 3 seconds while monitoring I_C for maximum value.
- ☐ 10. Remove the heat source and record the maximum value for I_C.
- ☐ 11. Allow the circuit to cool so that I_C returns to a value approximately that observed in Step 8.
- ☐ 12. Remove power from the circuit.
- ☐ 13. Install a 1.5 Kohm resistor between the transistor emitter and ground.
- ☐ 14. Repeat Steps 5-12 for the new configuration.
- ☐ 15. Remove the 1.5 Kohm resistor.
- ☐ 16. Install a 4.7 Kohm resistor between the transistor emitter and ground.
- ☐ 17. Repeat Steps 5-12 for the new configuration.
- ☐ 18. Calculate the changes for I_C for each configuration.
- ☐ 19. Reassemble the circuit per Circuit 2 Schematic, but do not apply power.
- ☐ 20. Have your instructor check the circuit.
- ☐ 21. Energize circuit and adjust power supply to 15 volts.
- ☐ 22. Measure and record I_B.
- ☐ 23. Measure and record I_C.
- ☐ 24. Hold the heat source near but not touching the transistor for approximately 3 seconds while monitoring I_C for maximum value.

Job Sheet 11

☐ 25. Remove the heat source and record the maximum value for I_C.

☐ 26. Remove power from the circuit.

☐ 27. Leaving the 220 Kohm resistor connected to the base circuit, disconnect the other end of the 220 Kohm.

☐ 28. Connect the 220 Kohm resistor's free lead to the collector circuit.

☐ 29. Repeat Steps 21-26 for the new configuration.

☐ 30. Compute the changes in I_C for the two configurations.

☐ 31. Discuss your results with your instructor; be prepared to discuss the following points:

- What is the function of each branch of the first circuit in the initial configuration?
- What is the function of the first circuit?
- What is the effect of heat on the first circuit?
- What is the effect of changing resistor values in the first circuit?
- How would you answer the above questions for the second circuit?

☐ 32. Disassemble circuit and return equipment and materials to their proper storage location.

Evaluator's comments: ______________________________

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Job Sheet 11

Table 1—Circuit 1

Resistor Value (RE)	I_B	I_C (ambient)	I_C (heated)	ΔI_C
No resistor				
1.5 Kohms				
4.7 Kohms				

Table 2—Circuit 2

Condition	I_B	I_C (ambient)	I_C (heated)	ΔI_C
Voltage Divider Across V_{CC}				
Collector Feedback				

Discrete Semiconductor Devices and Circuits
Unit 1

Job Sheet 12— Construct and Test a Push-Pull Amplifier

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
• Equipment was set up correctly	________
• Correct procedures were followed	________
• Circuit was correctly wired	________
• Student demonstrated an understanding of the applicable principles	________

Introduction: One popular configuration of transistor-based amplifier is the *push-pull amplifier*. It is called a push-pull amplifier because it uses two transistors, each of which is on during one-half of the AC cycle. The advantage of this configuration is that there is not as much of a power loss as with circuits that biased only during one alternation of the AC cycle. For this reason, push-pull amplifiers are often used as output amplifiers for maximum power gain.

There are two major approaches to push-pull amplifier designs. One is called the *complementary symmetry* configuration. *Complementary* refers to two seemingly opposite things that together make a complete something else. In this case, the complements are a PNP and an NPN transistor. *Symmetry* is characteristic balance between the two halves of something, often with the halves being mirror (reversed) images of one another. A complementary symmetry configuration has a PNP subcircuit and an NPN subcircuit—usually emitter-follower (common-collector) arrangements—that are essentially the same except for the transistors. The other common method of constructing push-pull amplifier circuits is the use of a transformer or pair of transformers, like the one you will build in this job sheet. The input transformer is center-tapped so that only half of the transformer is conducting at any time, with each half being fed to one of the transistors.

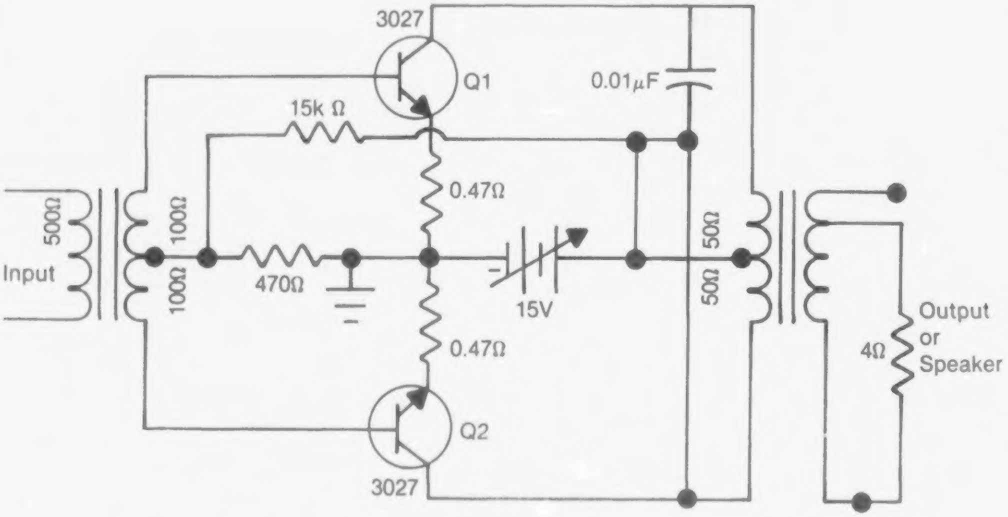
Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Regulated power supply
- Transformer, 500-ohm primary with 200-ohm center-tapped secondary
- Transformer, 100-ohm center-tapped primary with 4-ohm secondary
- Audio frequency signal generator
- Oscilloscope

Job Sheet 12

- Multimeter
- Test leads
- Two transistors (2N3027 for example)
- 15 Kohm resistor, ½-watt
- 470 ohm resistor, ½-watt
- 4 ohm resistor, 2 watts
- Two 0.47 ohm resistors, 2 watts
- 0.01 µF capacitor
- Low-voltage conductor
- Mounting surface and hardware
- Graph paper
- Pencil and paper
- Table at end of job sheet
- Circuit drawing


3027
Q1
15k Ω
0.01µF
0.47Ω
500Ω
Input
100Ω
100Ω
470Ω
15V
50Ω
50Ω
0.47Ω
Output or Speaker
4Ω
Q2
3027

B. Procedure

☐ 1. Assemble the circuit per the drawing, but do **not** apply power to the circuit.

☐ 2. Have your instructor check your circuit.

☐ 3. Energize the circuit and adjust the power supply to 15 volts.

☐ 4. Measure and record the base-emitter voltage (V_{BE}) of Q1.

☐ 5. Measure and record the voltage drop across the 0.47-ohm resistor of Q1.

Job Sheet 12

☐ 6. Compute the emitter current for Q1 using Ohm's Law.

☐ 7. Repeat Steps 4-6 for Q2.

☐ 8. Connect the AF generator to the input transformer and set the output of the generator to 1000 Hz.

☐ 9. Connect the oscilloscope across the 4-ohm load on the secondary of the output transformer.

☐ 10. Adjust the AF generator for maximum undistorted output as displayed on the oscilloscope and sketch the waveform.

☐ 11. Disconnect the oscilloscope.

☐ 12. Connect the oscilloscope across the input and adjust for a stable waveform.

☐ 13. Sketch the input waveform.

☐ 14. Disconnect the oscilloscope.

☐ 15. Connect the oscilloscope across the base-emitter junction of Q1 and adjust for a stable waveform.

☐ 16. Sketch the input waveform.

☐ 17. Repeat Steps 14-16 for Q2.

☐ 18. Remove power from the circuit.

☐ 19. Discuss your results with your instructor; be prepared to discuss the following points:

- What is the function of each branch of the circuit?
- How does the function of the transistors change as the circuit operates?
- Are the values recorded in the table what you expected?
- Is the signal phasing inverted? Why or why not?
- Would you expect similar results if this were a complementary symmetry amplifier? What would be the same? What would be different?

☐ 20. Disassemble circuit and return equipment and materials to their proper storage location.

Job Sheet 12

Evaluator's comments: ____

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Job Sheet 12

Transistor	V_{BE}	I_E	V_{out} (peak to peak)	V_{in} (peak to peak)
Q1				
Q2				

Notes:

Discrete Semiconductor Devices and Circuits
Unit 1

Job Sheet 13— Construct and Test a Two-Stage, Direct-Coupled Amplifier

Name ______________________ Attempt Number __________

Date ______________________ Overall Rating __________

Evaluation criteria	**Rating**
• Equipment was set up correctly	________
• Correct procedures were followed	________
• Circuit was correctly wired	________
• Student demonstrated an understanding of the applicable principles	________

Introduction: The amplifier in this project is a multistage amplifier—that is, a number of amplifiers that have been cascaded together. In this particular circuit, two amplifiers have been directly coupled to each other. Recall that coupling is a method of joining circuits and that circuits may also be coupled by means of resistive-capacitive connections, impedance connections, or transformers. Direct coupling is most often used in amplifier circuits with few stages because noise tends to increase in directly coupled circuits. But the method is convenient and useful as you will see in this project.

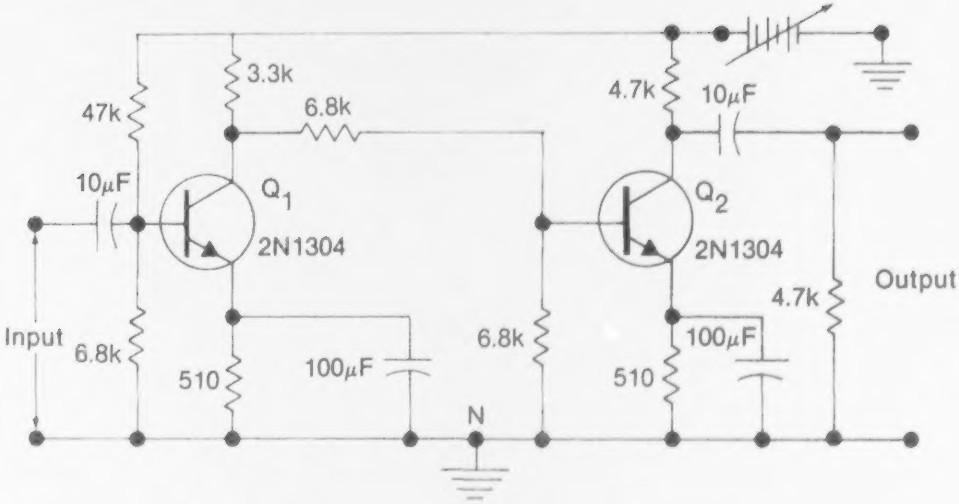
Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Regulated DC power supply (0-20 volts)
- Audio frequency signal generator
- Oscilloscope
- Multimeter or voltmeter
- Test leads
- Two transistors (2N1304 for example)
- Two 510 ohm resistors, ½-watt
- Two 47 Kohm resistors, ½-watt
- Two 4.7 Kohm resistors, ½-watt
- Three 6.8 Kohm resistors, ½-watt
- 3.3 Kohm resistor, ½-watt
- Two 10 μF capacitors, 20 volts
- Two 100 μF capacitors, 20 volts

Job Sheet 13

- Low-voltage conductor
- Mounting surface and hardware
- Graph paper
- Pencil and paper
- Table at end of job sheet
- Circuit drawing


3.3k
47k
6.8k
4.7k
10μF
10μF
Q1
2N1304
Q2
2N1304
4.7k
Output
Input
6.8k
510
100μF
N
6.8k
100μF
510

B Procedure

☐ 1. Assemble the circuit per the drawing, but do **not** apply power to the circuit.

☐ 2. Connect the oscilloscope across the 4.7 Kohm output resistor.

☐ 3. Connect the AF generator to the input terminals and set the frequency for 1000 Hz with the voltage level at 0.

☐ 4. Have your instructor check your circuit.

☐ 5. Energize the circuit and adjust the power supply to 15 volts.

☐ 6. Measure and record the voltage with respect to ground for the emitter of Q1.

☐ 7. Measure and record the voltage with respect to ground for the base of Q1.

☐ 8. Measure and record the voltage with respect to ground for the collector of Q1.

Job Sheet 13

☐ 9. Repeat Steps 6-8 for Q2.

☐ 10. Adjust the AF generator to obtain an undistorted display on the oscilloscope.

☐ 11. Measure and record the peak-to-peak output voltage using the oscilloscope.

☐ 12. Sketch the output waveform.

☐ 13. Measure and record the peak-to-peak input voltage at the base of Q2.

☐ 14. Measure and record the peak-to-peak output voltage at the collector of Q1.

☐ 15. Measure and record the peak-to-peak input voltage at the base of Q1.

☐ 16. Compute the voltage gain of the first stage and express it as decibels.

☐ 17. Compute the voltage gain of the second stage and express it as decibels.

☐ 18. Connect the oscilloscope to the input of the first stage (Q1 base) and adjust the AF generator for the maximum undistorted signal at 10 KHz.

Note: Adjust the power supply as necessary to maintain a constant input voltage.

☐ 19. Measure and record the voltage across the output resistor.

☐ 20. Sketch the waveform.

☐ 21. Repeat Steps 18-20 for each frequency listed in the table at the end of the job sheet.

☐ 22. Remove power from the circuit.

☐ 23. Make a graph of the output voltages measured at Step 19 versus the frequency settings, with the voltage on the vertical axis and the frequency on the horizontal axis.

☐ 24. Discuss your results with your instructor; be prepared to discuss the following points:

- What is the function of each branch of the circuit?
- How do the voltage readings compare at the output of the two stages?
- How does the output of the two stages compare to the

overall voltage gain of the multistage amplifier?
- How does voltage gain vary with regard to signal frequency?
- What is the purpose of the voltage divider between the two stages?

☐ 25. Disassemble circuit and return equipment and materials to their proper storage location.

Evaluator's comments: ____

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Job Sheet 13

Table 1—Transistor Voltages

Transistor	V_{Base}	$V_{Collector}$	$V_{Emitter}$
Q1			
Q2			

Table 2—Voltage Gain Data

Amplifier Stage	V_{out} (P-P)	V_{in} (P-P)	A_V	A_V (dB)
First				
Second				
Overall				

Table 3—Output Versus Frequency

10 KHz	8 KHz	6 KHz	4 KHz	2 KHz	1 KHz	800 Hz	600 Hz	400 Hz	200 Hz

Notes:

Discrete Semiconductor Devices and Circuits
Unit 1

Job Sheet 14— Construct and Test a Darlington Pair Amplifier

Name ______________________ Attempt Number __________

Date ______________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedure was done correctly	________
• Equipment was used correctly	________
• Circuit was correctly wired	________
• Student demonstrated an understanding of the applicable principles	________

Introduction: One of the most common direct-coupled transistor combinations is called a *Darlington circuit* or *Darlington pair circuit* or sometimes as a *compound connection*. The configuration is so popular that it is available in discrete packages called Darlington transistors or Darlington amplifiers. The reason for such popularity is that the connection is simple and straightforward, yet it yields a tremendous advantage in current gain. In effect, the overall gain is approximately equate to the product of the β of the two transistors. This makes the design very useful with small input signals.

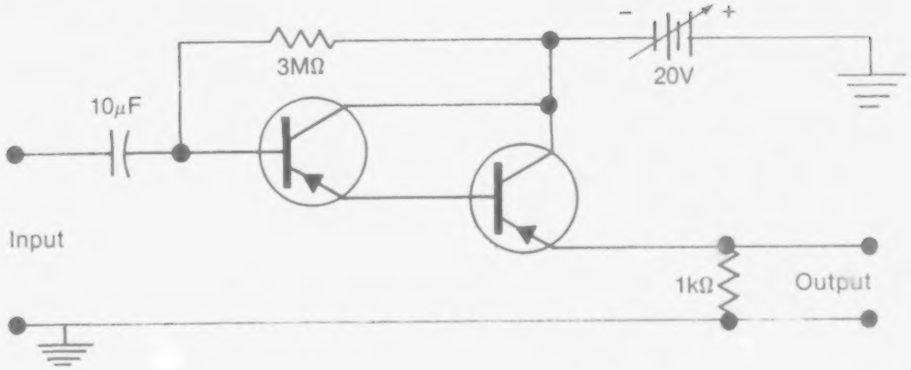
The design is actually a number of configurations because it can use either NPN or PNP transistors and because the transistors can be coupled as common-emitter, common-base, or common-collector pairs. In this job sheet, you will build and test a basic amplifier circuit using a Darlington pair.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- DC power supply, 0-40 volts
- Audio frequency signal generator
- Oscilloscope
- Test leads
- Two PNP transistors
- 3 Mohm resistor, ½-watt
- 1 Kohm resistor, 1-watt

- 10 µF capacitor, 25 volts
- Low-voltage conductor
- Mounting surface and hardware
- Pencil and paper
- Circuit drawing



B. Procedure

☐ 1. Assemble circuit per drawing with the switch open, but do **not** apply power.

☐ 2. Connect the oscilloscope to the output of the AF generator

☐ 3. Connect the AF generator to the circuit input.

☐ 4. Have your instructor check your circuit.

☐ 5. Energize the circuit and adjust the power supply to 20 volts.

☐ 6. Set the oscilloscope for 1000 Hz and adjust for a 4 volts peak-to-peak display.

☐ 7. Leaving the oscilloscope connected to the AF generator output, place the generator leads to the Darlington amplifier input leads.

☐ 8. Move the oscilloscope leads from the input to the output and measure the output voltage (peak-to-peak).

☐ 9. Remove power from the circuit.

☐ 10. Compute the overall voltage gain as a ratio and convert it to decibels.

Job Sheet 14

☐ 11. Discuss your results with your instructor; be prepared to discuss the following points:

- What is the purpose of collecting the transistors in this fashion?
- Compare the β specification for the transistors used to the overall gain calculated for the circuit. Is the overall gain approximately equal to β^2?
- What level of impedance would you expect this circuit to exhibit?
- Which configuration of Darlington pair (CE, CC, CB) would you expect to provide the greatest gain or would there be any difference? Why?

☐ 12. Return equipment and materials to their proper storage location.

Evaluator's comments: ______________________________

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Discrete Semiconductor Devices and Circuits
Unit 1

Job Sheet 15— Construct and Test a Hartley Oscillator

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedure was done correctly	________
• Equipment was used correctly	________
• Circuit was correctly wired	________
• Student demonstrated an understanding of the applicable principles	________

Introduction: You have often used oscillators, perhaps without realizing it. Oscillators are used to convert DC to AC, which makes them useful for generating waveforms. Thus, signal generators, oscilloscopes, and other pieces of electronic test equipment often use oscillators. Devices that require steady pulsing signals use oscillators for timers (including many digital watches). Equipment that must produce signals of specific frequencies—such as electronic musical instruments, touch-tone telephones, garage-door openers, remote controls for TVs and CD players—generally use oscillators. Virtually all radio and television transmissions are sent and received through the use of oscillators. Because of this wide-spread usage, it is important that the electronics technician understand how oscillators operate.

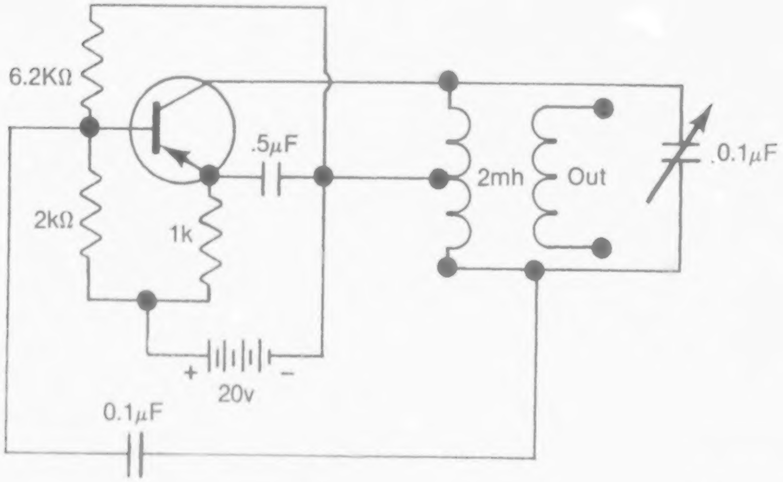
Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- RF transformer, 2 mH
- Regulated power supply, 0-25 VDC, or equivalent battery
- Oscilloscope
- Frequency counter (optional)
- Test leads
- PNP transistor
- 1 Kohm resistor, 2 watts
- 2 Kohm resistor, 2 watts
- 6.2 Kohm resistor, 2 watts
- 0.1 µF capacitor, 50 volts
- 0.5 µF capacitor, 50 volts

Job Sheet 15

- 0.1 μF variable capacitor, 50 volts
- Low-voltage conductor
- Mounting surface and hardware
- Pencil and paper
- Circuit drawing



B. Procedure

☐ 1. Assemble the circuit per drawing, but do **not** apply power.

☐ 2. Connect the oscilloscope to the output winding of the RF transformer.

☐ 3. Have your instructor check your circuit.

☐ 4. Energize the circuit and the power supply to 20 volts.

☐ 5. Observe the waveform and sketch it.

☐ 6. Adjust the variable capacitor up and down and observe the changes in waveform frequency.

☐ 7. Adjust the waveform to the lowest frequency obtainable.

☐ 8. Measure and record the peak-to-peak voltage.

☐ 9. Sketch the waveform and record the frequency.

☐ 10. Adjust the waveform to the highest frequency obtainable.

Job Sheet 15

☐ 11. Measure and record the peak-to-peak voltage.

☐ 12. Sketch the waveform and record the frequency.

☐ 13. Continue operating the circuit at the highest obtainable frequency, place your finger lightly against the case of the transistor, and observe any changes in the waveform that may result from the heating from your finger.

☐ 14. Turn off power to the circuit.

☐ 15. Replace the transistor with another transistor of the same part number and family.

☐ 16. Repeat Steps 4-14 with the replacement transistor.

☐ 17. Discuss your results with your instructor; be prepared to discuss the following points:

- What is the purpose of each portion of the circuit?
- What causes the oscillation?
- What were the lowest and highest frequencies at which you could obtain a stable waveform?
- What was the effect of heat on the circuit? Did the highest frequency increase or decrease as the circuit got warmer?
- Was there much difference in the performance of the two transistors? What would account for this difference (if any)?

☐ 18. Disassemble the circuit and return equipment and materials to their proper storage area.

Evaluator's comments: ____

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Discrete Semiconductor Devices and Circuits
Unit 1

Job Sheet 16— Test and Replace Silicon-Controlled Rectifiers

Name ______________________ Attempt Number __________

Date ______________________ Overall Rating __________

Evaluation criteria	**Rating**
• Correct procedures were followed	________
• Equipment was configured correctly	________
• Equipment was used correctly	________
• Status of SCR was correctly determined	________

Introduction: One reason for using SCRs and other gated thyristors in electronic circuits is that they can be triggered with a high degree of precision. Because the SCR is basically a triggered diode, its testing is fairly simple. As with a diode, the technician must verify that the SCR promotes conduction in one direction and blocks it in the other. Secondly, the operation of the gate must be verified. This job sheet presents a procedure for accomplishing these tests.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Multimeter
- Test leads
- Low-voltage jumper wire
- Assortment of SCRs provided by instructor
- Two component trays, one marked *Good SCRs* and one marked *Rejected SCRs*

B. Procedure

☐ 1. Determine polarity of meter leads.

☐ 2. Set multimeter to function as ohmmeter on the R x 1K scale.

☐ 3. Select SCR to be tested.

Job Sheet 16

☐ 4. Connect the positive meter lead to the anode of the SCR and the negative meter lead to the cathode of the SCR; record reading.

☐ 5. If resistance is low, go to Step 12; otherwise, continue procedure.

☐ 6. Connect the jumper wire from the anode to the gate of the SCR.

☐ 7. Connect the positive meter lead to the anode of the SCR and the negative meter lead to the cathode of the SCR.

☐ 8. If resistance is high, go to Step 12; otherwise, continue procedure.

☐ 9. Remove the jumper wire from the SCR.

☐ 10. Connect the positive meter lead to the anode of the SCR and the negative meter lead to the cathode of the SCR.

☐ 11. If the resistance is different than what was observed at Step 4, go to Step 12; otherwise, go to Step 13.

☐ 12. Reject the SCR and then go to Step 14.

☐ 13. Accept the SCR and then go to Step 14.

☐ 14. Repeat Steps 3-13 for any SCRs remaining to be tested.

☐ 15. Discuss your results with your instructor.

☐ 16. Return equipment and materials to their proper storage area.

Evaluator's comments: ______________________________

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Discrete Semiconductor Devices and Circuits
Unit 1

Job Sheet 17— Troubleshoot Discrete Solid-State Device Circuits

Name ________________________________ Attempt Number ____________

Date ________________________________ Overall Rating ____________

Evaluation criteria	**Rating**
• Troubleshooting procedure was well designed	________
• Equipment was used correctly	________
• Correct problems were identified	________
• Problems were correctly repaired	________

Introduction: For this job sheet, your instructor will provide you with a semiconductor device or circuit that has one or more problems. Those problems may be defective components, shorts, opens, incorrect wiring, and other problems that an electronics technician is likely to encounter in this type of circuit. Using what you have learned about troubleshooting, component testing, and semiconductor circuit operation, you will be required to design a troubleshooting procedure for the circuit and then carry out that procedure to identify and correct problems in the circuit.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Semiconductor circuit or device provided by instructor
- Paper and pencil
- Equipment as required by troubleshooting procedure
- Materials as required by troubleshooting procedure

B. Procedure

☐ 1. Examine device for preliminary troubleshooting assessment.

☐ 2. Define troubleshooting procedure in writing.

☐ 3. Discuss troubleshooting procedure with instructor.

Job Sheet 17

☐ 4. Conduct troubleshooting procedure.

☐ 5. Identify problems and record results of troubleshooting.

☐ 6. Repair equipment to return to operational state.

☐ 7. Verify that repair has returned equipment to an operational state.

☐ 8. Discuss the problem and your response with your instructor.

☐ 9. Return equipment and materials to their proper storage location.

Evaluator's comments: ____

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Linear Integrated Devices and Circuits
Unit 2

Objective Sheet

Unit Objective

After completing this unit, the student should be able to discuss linear integrated circuits and construct and test such circuits. The student should demonstrate these competencies by completing the assignment sheets and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms associated with linear integrated devices and circuits to their correct definitions.
2. Distinguish between active and passive components.
3. Match types of integrated circuit construction to their correct descriptions.
4. List ways of classifying IC packages.
5. Explain the meaning of the elements in an IC part number.
6. Label the features of a dual in-line package integrated circuit.
7. Describe methods for identifying the number one pin on typical integrated circuit packages.
8. List advantages of using integrated circuit devices as compared to equivalent circuits consisting of discrete components.
9. Classify ICs by the number of components they contain.
10. State guidelines for working with integrated circuits.
11. Classify common integrated circuit devices as linear or digital.
12. Classify amplifiers by their transfer functions.
13. Match mathematical functions performed by amplifiers to their correct equations.
14. Identify types of differential circuits.
15. Match types of differential circuits to their correct descriptions.

Objective Sheet

16. Label the components of an operational amplifier.
17. Match the components of an operational amplifier to their correct functions.
18. Label the parts of the symbol for an operational amplifier.
19. Match the operational characteristics of an operational amplifier to their correct descriptions.
20. Match input-output parameters of an op-amp to their correct descriptions.
21. Match dynamic parameters of an op-amp to their correct descriptions.
22. Describe the characteristics of an inverting amplifier.
23. Describe the characteristics of a noninverting amplifier.
24. Distinguish between open-loop and closed-loop operation.
25. Complete statements regarding the relationship among gain, bandwidth, and feedback in a closed-loop op-amp.
26. Distinguish between summing and difference amplifiers by their characteristics.
27. Identify types of sinusoidal op-amp oscillators by their schematics.
28. Match nonsinusoidal op-amp oscillators to their correct descriptions.
29. Identify types of linear multivibrators by their schematics.
30. Complete statements regarding the characteristics of comparators.
31. Match types of op-amp comparators to their correct operational descriptions.
32. Complete statements about phase-locked loop operation.
33. Select from a list correct statements about the characteristics of active filters.
34. Match active filter circuits to their correct schematics.
35. Select from a list correct statements about transimpedance amplifiers.
36. Distinguish between IC switches and control devices by their descriptions.
37. Complete statements regarding IC timers.
38. Select from a list correct statements regarding IC counters.

Objective Sheet

39. Describe the function of IC transmitter and receiver devices.
40. Complete statements regarding the operation and principles of an RF circuit.
41. Complete statements regarding the operation and principles of an IF circuit.
42. Identify types of signal modulation by their waveforms.
43. Complete statements about the characteristics of microwaves.
44. List uses of microwave circuits in electronic systems.
45. Describe the parts of a fiber optic circuit.
46. Complete statements about fiber optic circuits.
47. Complete statements about the operation of IC sensor devices.
48. List types of IC sensor stimuli.
49. Match types of photo-sensitive devices to their correct uses in linear circuits.
50. Match types of IC signal processing functions to their correct descriptions.
51. Calculate the closed-loop gain for an inverting and a noninverting amplifier. (Assignment Sheet 1)
52. Calculate the output voltage of a DC summing amplifier. (Assignment Sheet 2)
53. Determine specifications for commercially available op-amps. (Assignment Sheet 3)
54. Construct and test an inverting amplifier. (Job Sheet 1)
55. Construct and test a noninverting amplifier. (Job Sheet 2)
56. Construct and test a differential amplifier. (Job Sheet 3)
57. Construct and test a DC summing amplifier. (Job Sheet 4)
58. Construct and test a Hartley oscillator using an op-amp. (Job Sheet 5)
59. Construct and test a low-pass active filter. (Job Sheet 6)
60. Construct and test a timer circuit. (Job Sheet 7)
61. Troubleshoot linear circuits. (Job Sheet 8)

Linear Integrated Devices and Circuits
Unit 2

Information Sheet

1. Terms and definitions

a. **Attenuation**—Reduction in or loss of signal strength, especially as a reduction in amplitude

b. **Common mode**—Operating condition of an amplifier in which the input signals are identical in amplitude and duration

c. **Common-mode rejection ratio (CMRR)**—In a differential amplifier, the extent to which the circuit cancels unwanted signals, expressed as the ratio of the difference-mode gain to the common-mode gain

d. **Crosstalk**—Unwanted transfer of signals from one part of a device, circuit, or system to another part of the device, circuit, or system

e. **Cutoff point (cutoff frequency)**—Frequency at which an amplifier or filter begins rejecting signals or when a transistor amplification factor drops to 70.7 percent of its maximum value or 3 dB below maximum gain

f. **Deflection mode**—Type of sensor circuit operation in which sensing takes place as a result of the sensor being acted upon and physically affected

g. **Difference mode**— Operating condition of an amplifier in which the input signals are different in amplitude or duration

h. **Differentiation**—Mathematical function performed by amplifier circuits in which the output is equal to the slope of the input waveform

i. **Duty cycle**—The percent or decimal fraction amount of time within a given time period that a device or circuit is on or in some other specified state such as high that is equivalent to on

j. **Generating sensor**—Sensor device that converts inputs directly into electrical power for use in the sensor circuit

k. **Heterodyne**—To mix signals, and in particular radio signals, together to produce a sum or difference signal

l. **Integration**—Mathematical function performed by amplifier circuits in which the output is equal to the product of the area of the input waveform

m. **Inversion**—Mathematical function performed by amplifier circuits in which the output is 180° out-of-phase from an AC input signal or of the opposite polarity of a DC signal

n. **Modulating sensor**—Sensor device that requires an external power supply to provide electrical power for use in the sensor circuit

o. **Modulation**—Process of combining signals so that one signal, called the carrier, maintains its basic waveform but follows a pattern driven by the second signal or modulating signal

p. **Multivibrator**—Oscillator that produces a nonsinusoidal waveform

q. **Null mode**—Type of sensor circuit operation in which sensing takes place as a result of the sensor resisting movement from a point of balance

r. **Offset null circuit**—Op-amp circuit designed to compensate for input signal differences that result from imperfect matching of resistors, transistors, and other components

s. **Phase-locked loop**—An oscillator-driven circuit that modifies its output signal to keep its output phase, frequency, or both synchronized with a reference signal

t. **Power dissipation**—Power consumed by a device during its operation so that this power is not available for the output signal

u. **Relaxation oscillator**—Oscillator circuit that uses RC timing components to control the output signal frequency

v. **Signal-to-noise ratio (SNR)**—The ratio between the total signal (such as peak voltage) and that portion of the total signal that is unwanted; often expressed in decibels

w. **Slew rate**—Characteristic of an op-amp regarding how quickly the output can be changed between its upper and lower limits

x. **Virtual ground**—Ungrounded point in a circuit that acts as a ground for all practical purposes in terms of signal processing

2. **Active versus passive devices**

a. Active device—Circuit device capable of a dynamic function, such as amplification, oscillation, signal control, and that usually requires a power supply for operation

Examples: Transistor, SCR, magnetic amplifier

b. Passive device—Circuit device that is basically static in its operation that generally requires no power for its characteristic operation

Examples: Diode, capacitor, resistor, fuse

Information Sheet

3. **Integrated circuit construction**

   a. Monolithic—Integration of circuits into a single piece of semiconductor material

   b. Thin-film—Use of thin layers of metals and oxides that form components on a single substrate of insulating material such as glass or ceramic

   c. Thick-film—Deposition of components on a substrate through use of a process such as silk-screening

   d. Hybrid—Integrated circuit consisting of a combination of two or more of the other methods

4. **Ways of classifying IC packaging**

   a. Material

      Examples: Metal, plastic, ceramic

   b. Package design

      Examples: Dual in-line package, round case, TO 116

   c. Pin design

      Examples: Through-hole, leadless flat-pack, gull-wing connectors

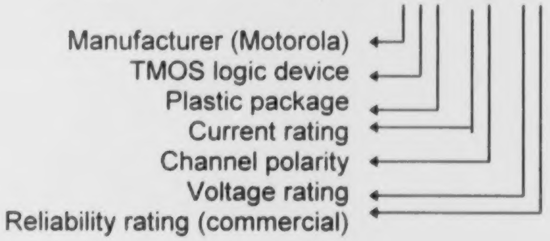
5. **Meaning of IC part numbers**

   a. Prefix—Generally one to three letters that identify the type of device or family of devices

   b. Part number—Three- or four-digit number that is assigned to the specific functionality of the device

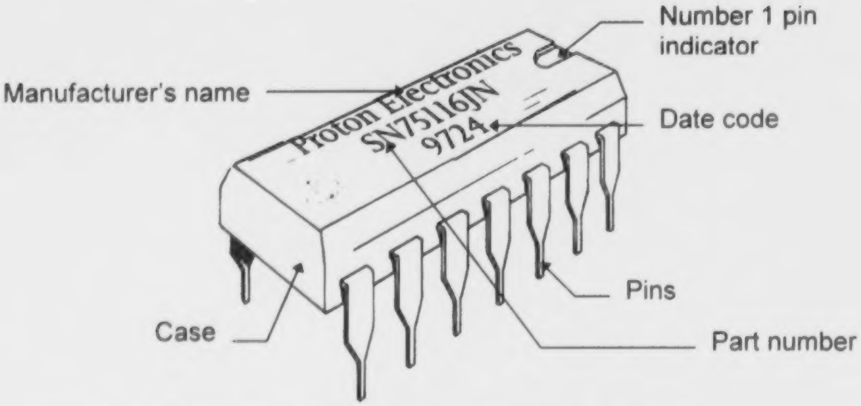
   c. Suffix—Various combinations of letters and symbols that have specific meanings regarding packaging, performance, reliability, and other device characteristics

      Example: Power MOSFET MTP10N10C


Manufacturer (Motorola)
TMOS logic device
Plastic package
Current rating
Channel polarity
Voltage rating
Reliability rating (commercial)

Information Sheet

6. Features of a dual in-line package integrated circuit



7. Number one pin on typical integrated circuit packages

Note: IC packages are marked to show the number one pin (usually a ground pin) or are *keyed* so that they can be installed in only one way.

a. Dual in-line package—When viewed from above with the notch or indentation on the right, the number one pin is on the right above the notch or indentation

b. Round case—When looking down on the pins, the first pin clockwise from the tab or aligned with the tab is the number one pin

c. Square packages—Marked with a dot on the case by the number one pin

8. Advantages of using integrated circuit devices as compared to equivalent circuits consisting of discrete components

Note: The disadvantages of using ICs include lower resistor accuracy, limited levels of achievable resistance and capacitance, inability to use inductors, and limited power dissipation. Still, their advantages make ICs the better suited for many applications.

a. ICs are more reliable due to fewer components to fail.

b. ICs require less power.

c. ICs generally cost less than the equivalent discrete components.

d. ICs save space and weight.

e. ICs are easier to fabricate.

f. ICs usually make it easier to find compatible circuit components.

Information Sheet

9. Classifications of ICs by the number of components they contain

a. Small-scale integration (SSI)—10 to 100 transistor equivalents

b. Large-scale integration (LSI)—100 to 100,000 transistor equivalents

c. Very large-scale integration (VLSI)—100,000 or more transistor equivalents

10. Guidelines for working with integrated circuits

a. Store ICs in ESD-protective containers.

b. Wear a grounded wrist strap when handling ICs.

c. Use properly grounded tools and equipment when connecting to ICs.

d. Use soldering equipment of the proper temperature range when soldering ICs.

e. Avoid overheating components during soldering.

f. Do not use acid solders or chloride or paste fluxes.

g. Do not install or remove ICs or PCBs with power applied.

h. Do not apply signals to inputs with power removed.

i. Consult data sheets for proper operational limits and conditions and connection requirements.

j. Use special test equipment to avoid shorting between terminals.

k. Do not use analog test equipment or continuity lights to check for shorts and opens.

11. Linear and digital integrated circuit devices

Note: The following list of ICs is representative of the types of circuits that are offered as integrated devices. Generally any kind of electronic circuit that consists of more than a few discrete components can be found in an IC package.

a. Linear devices

- Amplifiers
- Filters

- Oscillators
- Switches and control circuits
- Timers
- Counters
- Transmitters and receivers
- Sensors
- Power supply and regulation devices

b. Digital devices

- Signal conversion circuits
- Logic devices
- Memory devices
- Microprocessors

12. Types of amplifiers based on their transfer functions

a. Discrete component amplifiers

- Current amplifier—Current-controlled amplifier based primarily on bipolar transistors
- Transconductance amplifier—Voltage-controlled amplifier based primarily on field-effect transistors

b. Integrated circuit amplifiers

- Voltage amplifier—Direct-coupled multistage amplifier whose output is dependent on the input voltage

  Note: This type of amplifier is generally referred to as an *operational amplifier*.

- Transimpedance amplifier—Direct-coupled multistage amplifier whose output is dependent on the input current

Information Sheet

13. Mathematical functions performed by amplifiers

Note: Amplifiers are designed to increase the gain of a signal, but they can also be used to make mathematical changes in signal characteristics when assembled with the required circuit components. The following statements describe common mathematical functions performed with amplifier-based circuits and give equations that show what happens to the voltage output compared to the voltage input.

a. Addition—Two or more input signals are added together to produce a single output and is represented by the equation

$$V_{out} = V_1 + V_2 + \ldots V_n$$

Note: A circuit that performs addition may be referred to as an *adder*, *adding circuit*, or *summing circuit*. An application of such a circuit is in the making of a recording where the signals picked up by several microphones are added together. Because the equipment used in this application is an *audio mixer*, summing circuits are also referred to as mixers.

b. Subtraction—Two input signals are compared and the difference between them is provided as the output and is represented by the equation

$$V_{out} = V_1 - V_2$$

Note: At first it may appear that this operation would not result in amplification. However, even though voltage is decreased, gain can still be increased. Circuits that perform this operation are referred to as *subtracting*, *differential*, or *difference amplifier*.

c. Averaging—The output signal value is equal to the sum of the inputs divided by the number of inputs and is represented by the equation

$$V_{out} = \frac{V_1 + V_2 + \ldots V_n}{n}$$

d. Integration—The output is equal to the product of the area of the input waveform and is represented by the equation

$$V_{out} = \frac{(V)\,(t)}{K}$$

Note: Referred to as *integrators* or *integrating circuits*, these amplifiers contain an RC circuit. The effects of the RC circuit are represented by the constant *K* (R x C) in the formula, while *V* is the voltage of the waveform after the passage of time (*t*).

Information Sheet

e. Differentiation—The output is equal to the slope of the input waveform and is represented by the equation

$$V_{out} = K\frac{\Delta V}{\Delta t}$$

Note: The normal sine wave and many other waveforms have slope—that is, the voltage varies as time passes so that at 1 millisecond the signal is 3 volts and at 2 milliseconds the signal is 4 volts. In this example, the slope of the waveform is 1 volt/millisecond. In the *differentiator* or *differentiating amplifier*, an RC circuit is used to produce the desired mathematical operation, as represented by the constant K (R x C).

f. Inversion—The output signal is 180° out-of-phase with the input signal and is represented by the equation

$$V_{out} = -(V_{in})$$

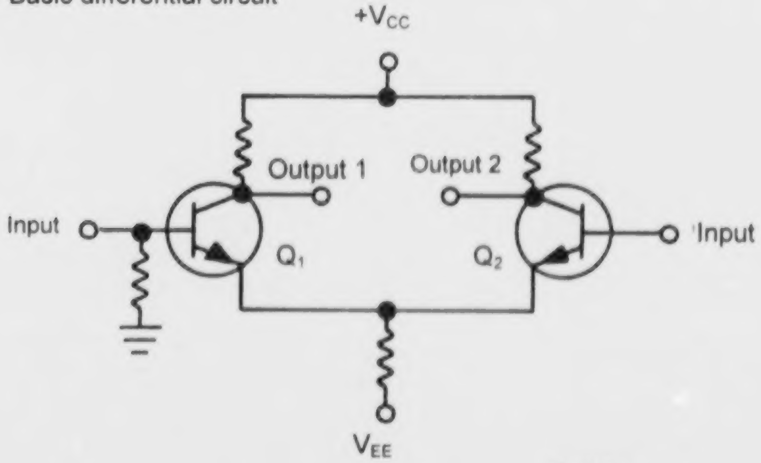
Note: With the output 180° out-of-phase, the output is simply the opposite polarity value of the input. Thus, a -5 volt DC input produces a +5 volt output. These types of amplifiers are normally referred to as *inverting amplifiers.* Inversion can be combined with other operations so that a circuit could be, for example, an inverting summing circuit. To determine the equation for the inverting version of another type of amplifier, simply replace V_{in} in the inversion equation with the right side of the appropriate equation.

g. Noninversion—The output signal is in-phase with the output signal and is represented by the equation

$$V_{out} = V_{in}$$

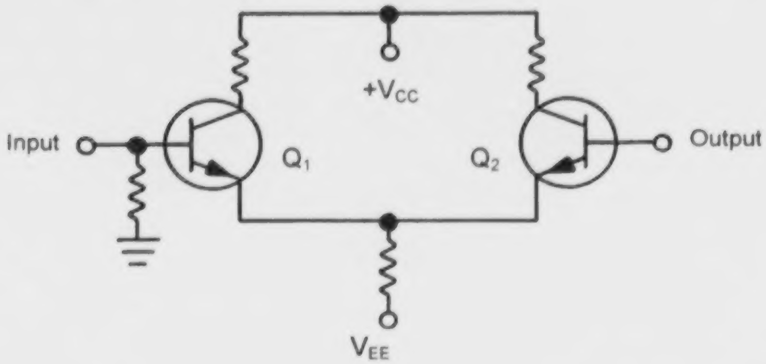
14. Types of differential circuits

a. Basic differential circuit

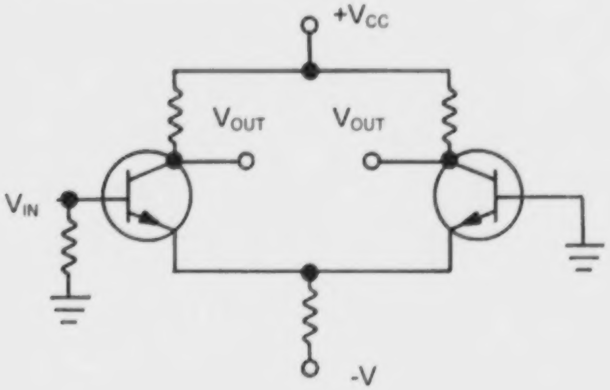


Information Sheet

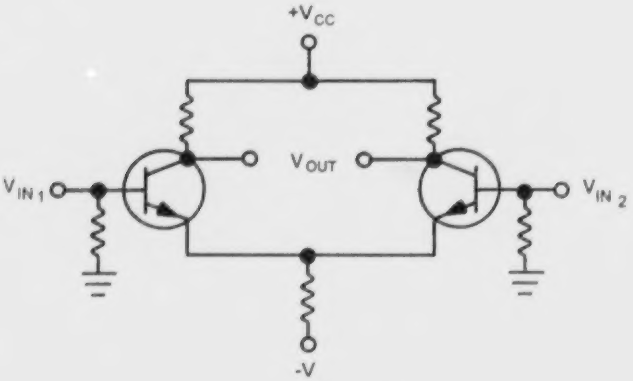
b. Single-input, single-output connection


$+V_{CC}$
Input
Q_1
Q_2
Output
V_{EE}

c. Single-input, differential output


$+V_{CC}$
V_{OUT}
V_{OUT}
V_{IN}
$-V$

d. Differential input, differential output


$+V_{CC}$
$V_{IN\,1}$
V_{OUT}
$V_{IN\,2}$
$-V$

15. Types of differential circuits

a. Basic differential circuit—Has two input terminals and two output terminals

b. Single-input, single-output connection—The output signal is in-phase with the input

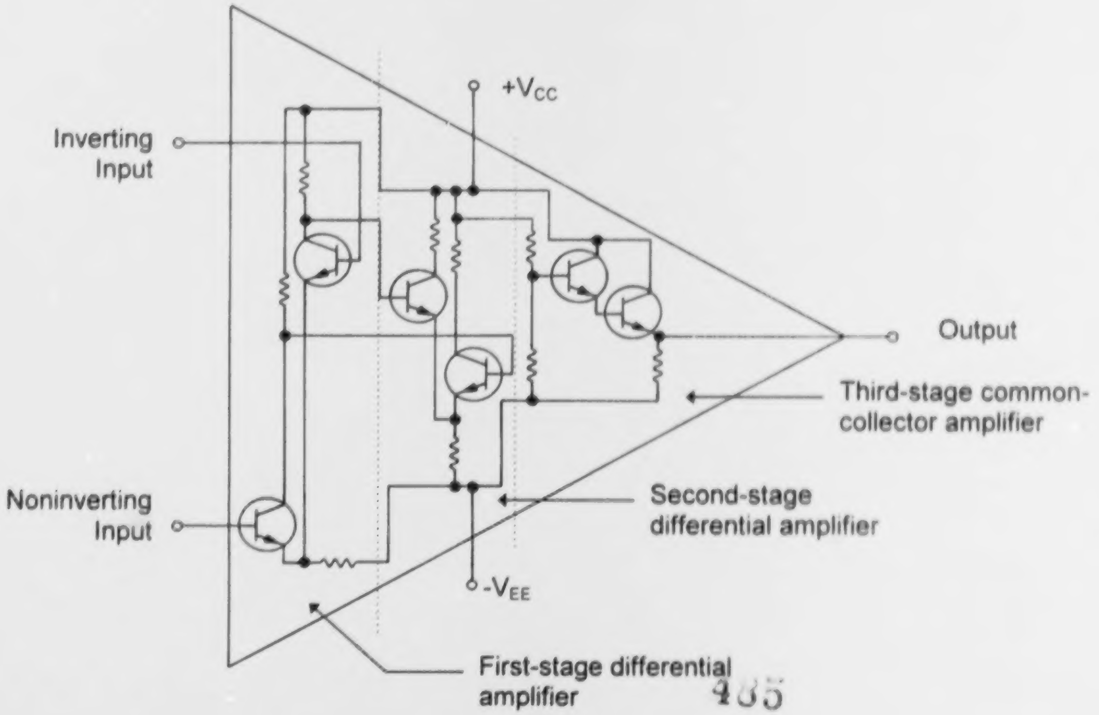
c. Single-input, differential output—Has one input terminal and two output terminals with one output in-phase with the input and the other 180° out-of-phase (though both outputs are of equal amplitude) and arranged so that the load can be connected to either or both outputs

d. Differential input, differential output—Has two input terminals 180° out-of-phase with each other and two output terminals whose voltage is shown in the formula

$V_{out} = A(V_{in1} - V_{in2})$

16. Components of an operational amplifier

Note: An operational amplifier or *op-amp* is an IC-version of various multistage amplifier circuits. Op-amps are widely used in electronic circuits. To understand how an op-amp operates, it is first necessary to understand the equivalent discrete components that an op-amp contains. The figure below shows the equivalent schematic for a typical op-amp.



+V$_{CC}$
Inverting Input
Output
Third-stage common-collector amplifier
Second-stage differential amplifier
Noninverting Input
-V$_{EE}$
First-stage differential amplifier

Information Sheet

17. Functions of operational amplifier components

a. Supply terminals—Provide power to the circuit

Note: The terminals have polarity.

b. Inverting input terminal—Provides signal input for signals that will be 180° out-of-phase at the output

c. Noninverting input terminal—Provides signal input for signals that will be in-phase at the output

d. First-stage differential amplifier—Amplifies input signal with high impedance and reduces signal noise

e. Second-stage differential amplifier—Uses the output of the first-stage amplifier to further reduce noise while ensuring good gain

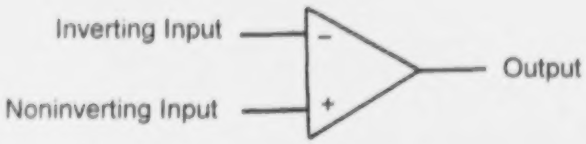
f. Third-stage common-collector amplifier—Ensures low output impedance

g. Output terminal—Provides modified signal to next circuit

h. Offset null circuit—Allows adjustment of circuit resistance to compensate for voltage differences that result from differences in circuit transistors and resistors

Note: Some op-amps are equipped with pins that allow adjustment of the IC's internal resistance. These pins are not shown in the figure with the previous objective.

18. Symbolic representation of an op-amp



19. Operational characteristics of an operational amplifier

a. Operating temperature—Ambient temperature range for which the op-amp will operate within the manufacturer's specifications

b. Supply voltage—Maximum positive and negative voltages that can be used to power the op-amp

c. Internal power of dissipation—Maximum power that an op-amp is capable of dissipating in a specified ambient temperature

Information Sheet

d. Input voltage (common mode voltage)—Maximum input voltage that can be simultaneously applied between both inputs and ground

e. Output short circuit duration—Time that the output of the op-amp can be short-circuited to ground or to either supply voltage

f. Differential input voltage—Maximum voltage that can be applied across the positive and negative inputs

20. Input-output parameters of an op-amp

a. Input resistance—Resistance at either input to the op-amp with the remaining input grounded

b. Input offset voltage—Voltage that must be applied to one of the input terminals to give a zero output voltage

c. Input bias current—Average of the currents flowing into both inputs

Note: Ideally both bias currents are equal.

d. Input offset current—Difference of the two input bias currents when the output is zero

e. Input voltage range (range of common mode input voltages)—Range of the voltage common to both inputs and ground

f. Output resistance—Resistance seen looking inward from the op-amp output

g. Output short-circuit current—Maximum output current that the op-amp can deliver to a load

h. Output voltage swing—Maximum peak output voltage that the op-amp can supply without saturation or clipping

21. Dynamic parameters of an op-amp

a. Open-loop voltage gain—Ratio of the output to input voltage of the op-amp without external feedback

b. Rise time—The 10-to-90-percent closed-loop, step-function response time of an amplifier under small signal conditions

c. Large-signal voltage gain—Ratio of the maximum voltage swing to the change in the input voltage required to drive the output from zero to a specified voltage

Information Sheet

d. Slew rate—Maximum rate of change of output voltage under large-signal conditions

e. Common-mode rejection ratio (CMRR)—Measure of the ability of the op-amp to reject signals that are simultaneously present at both inputs; generally expressed in decibels

f. Channel separation—Amount of crosstalk between op-amps when more than one op-amp is present in a single package

22. Characteristics of an inverting amplifier

Note: The inverting amplifier is the most popular op-amp configuration. The input signal is fed into the inverting terminal of the op-amp.

a. The output is 180° out-of-phase with the input.

Note: An AC signal will have the opposite alternations and a DC signal will be the opposite polarity.

b. The voltage gain of the op-amp stage is equal to the ratio between R_f to R_i.

c. The input impedance is equal to the value of R_i.

23. Characteristics of a noninverting amplifier

a. Output is in-phase with the output.

Note: A DC output will have the same polarity as the input.

b. The output signal is equal to the difference between the input signal applied to the noninverting input and the feedback signal applied to the inverting input.

c. The stage gain may be obtained through the equation

$$A_V = 1 + \frac{R_f}{R_i}$$

d. The input impedance is very high, greater than the input impedance of the op-amp.

24. Open-loop versus closed-loop operation

a. Open-loop—No feedback is used

b. Closed-loop with degenerative feedback—A portion of the output signal is directed back to the inverting input signal

Note: Degenerative feedback is also referred to as *negative* or *inverse feedback*. Degenerative denotes that the signal fed back to the input signal has been inverted and is the opposite polarity of the input signal, thus reducing gain.

c. Closed-loop with regenerative feedback—A portion of the output signal is directed back to the noninverting input terminal

Note: Regenerative feedback is also referred to as *positive feedback* and serves to increase input signal strength for it is the same polarity as the input signal.

25. Relationship among gain, bandwidth, and feedback in a closed-loop op-amp

a. Degenerative feedback decreases gain

b. Regenerative feedback increases gain.

c. Degenerative feedback increases the bandwidth.

d. Regenerative feedback decreases the bandwidth.

e. The gain-bandwidth product is constant for a given op-amp.

26. Characteristics of DC summing and difference amplifiers

a. DC summing circuit

- The circuit has two or more inputs with one output.
- All inputs feed into the negative terminal of the op-amp.
- The common connection for the input resistors is known as the *summing point*.

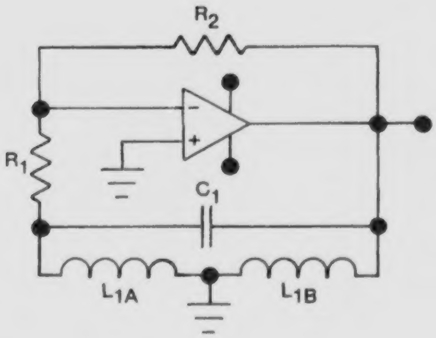
b. DC difference circuit

- The circuit has two inputs and one output.
- One input feeds into the negative terminal of the op-amp and the other input feeds into the positive terminal of the op-amp.
- The gain of the circuit is determined by the relationship of the resistor values.

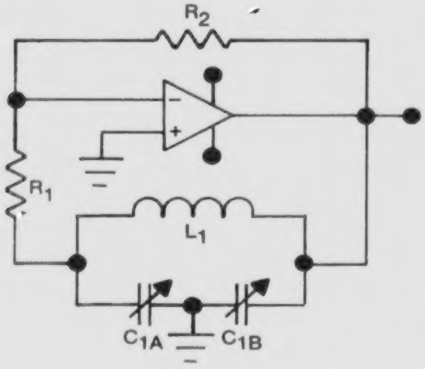
Information Sheet

27. Schematics for types of sinusoidal op-amp oscillators

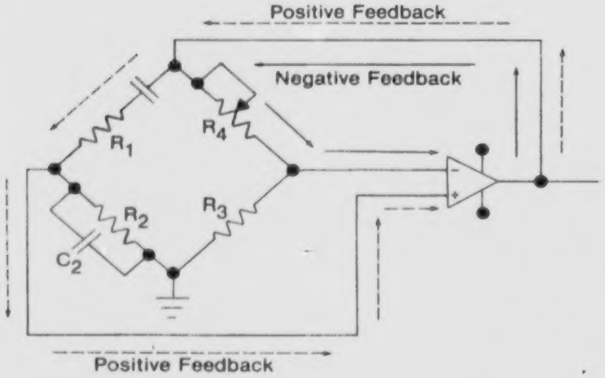
a. Hartley oscillator


R2
R1
C1
L1A
L1B

b. Colpitts oscillator


R2
R1
L1
C1A
C1B

c. Wein bridge oscillator


Positive Feedback
Negative Feedback
R1
R4
R2
R3
C2
Positive Feedback

Information Sheet

28. Non-sinusoidal op-amp oscillators

Note: Oscillators that produce nonsinusoidal waveforms are referred to as *relaxation oscillators* or *multivibrators.*

a. Astable (free-running or clock) multivibrator—Produces a square-wave output, whose values are determined by the circuit components

b. Monostable (one-shot or single-shot) multivibrator—Produces a constant output until a trigger signal is received, which drives the waveform to a second level where it remains until a specific duration of time has passed, whereupon it reverts back to the original level

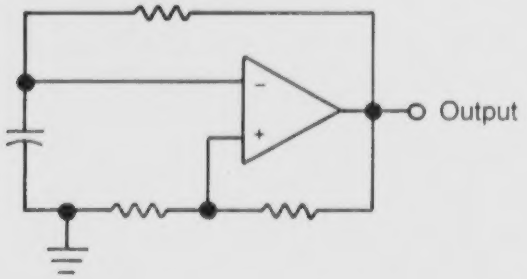
Note: The net effect of these alterations between two levels at prescribed intervals is the production of a square-wave output.

c. Bistable (flip-flop) multivibrator—Operates like a monostable multivibrator, except that it has two stable states so that it can remain in either until a trigger signal is received or other conditions are met

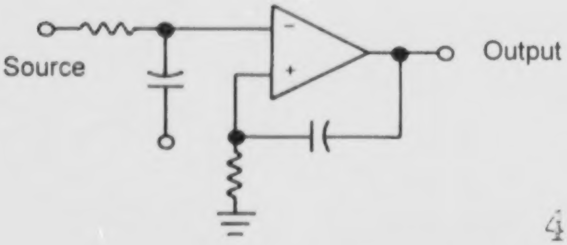
Note: Bistable multivibrators are ideally suited for many digital applications and are widely used in such circuits. Flip-flop design variations, operation, and applications are more completely covered in *Digital Electronics and Introduction to Microprocessors.*

29. Schematics for linear multivibrators

a. Astable multivibrator



b. Monostable multivibrator



Information Sheet

30. Characteristics of a comparator

a. Monitors a reference signal.

b. Changes output based on the value of the input compared to the value of the reference signal.

c. The amount of time between the detection of a difference between the input signal and the reference signal until the output signal changes is referred to as *propagation delay*.

d. The points at which the output signal changes are called *trip points* or *threshold points*.

e. The difference between the high and low trip points of a comparator is called *hysteresis*.

Note: Hysteresis can be helpful in a comparator circuit to prevent output changes caused by signal noise. If the comparator has a single threshold point or if the threshold points are too close together, noise in the input signal may cause the input signal that is near a threshold point to fluctuate back and forth over the trip point, causing erratic changes in the output.

f. A comparator may or may not use a feedback loop.

Note: There are several component combinations that can be used to build a comparator. As an integrated circuit, the comparator may be based on an op-amp or on a dedicated comparator circuit that resembles an op-amp. Such a comparator usually has a single output with an inverting and a noninverting input, with the reference signal being fed to the noninverting terminal. Some comparators contain logic devices and more advanced circuits, such as sample and hold circuits. The technician must also be careful not to confuse a linear comparator with a device with the same name that is used in digital applications to compare sets of information (data).

31. Types of op-amp comparators

a. Voltage comparator—Monitors a reference voltage and changes output when the input voltage varies from the reference voltage

b. Zero crossing detector—Changes output each time the input signal waveform switches from positive to negative or from negative to positive

c. Level sensing circuit—Monitors a reference voltage and changes output once the input signal rises above the reference level

Information Sheet

d. Window comparator—Uses two op-amps so that each monitors either an upper or a lower threshold, with the output signals varying based on the input signal level

Note: The circuit may be set up to provide power when the input signal is within the window (between the threshold points), above the upper threshold, below the lower threshold, or either above or below the thresholds. The output for these various conditions may come from one comparator, both comparators, or neither comparator.

e. Schmitt trigger--Uses positive feedback to the reference voltage to provide a narrow upper and lower threshold so that noise distortion will not cause undesired output changes

32. Phase-locked loop operation

a. Phase-locked loop (PLL) is a circuit consisting of a phase comparator, a voltage-controlled oscillator (VCO), and an amplifier.

b. The input signal is processed by the phase comparator and compared to the VCO signal.

c. The phase comparator outputs an error signal if there is a frequency (phase) difference between the two signals.

d. The VCO shifts frequencies until it matches the input signal.

e. Once the signals match, the VCO locks onto the input signal frequency and changes with it as long as it is within an acceptable range.

33. Characteristics of active filters

a. Active filters perform functions similar to passive filters but have the added capability of adjusting for various frequencies.

b. The adjustment capability is provided through the use of an op-amp and an RC feedback circuit.

c. In a low-pass active filter, low frequencies are routed through the RC branch, while high frequencies are shunted to ground.

d. In a high-pass active filter, high frequencies are routed through the RC branch, while low frequencies are shunted to ground.

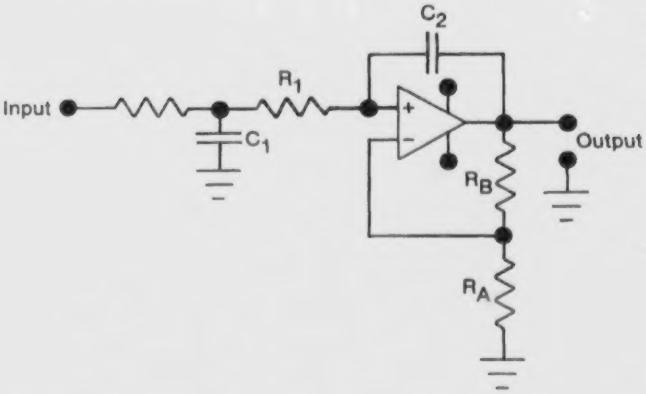
e. In a band-pass active filter, two RC branches or two op-amps are used to filter frequencies above and below a given bandwidth.

f. In a notch active filter, the frequencies within a given range around a center frequency are filtered and signals outside that range pass through.

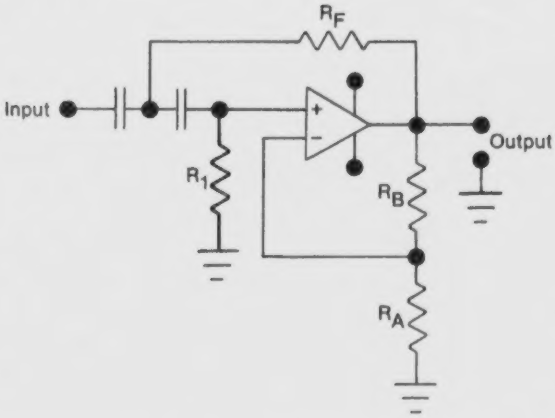
Information Sheet

34. Schematics for active filters

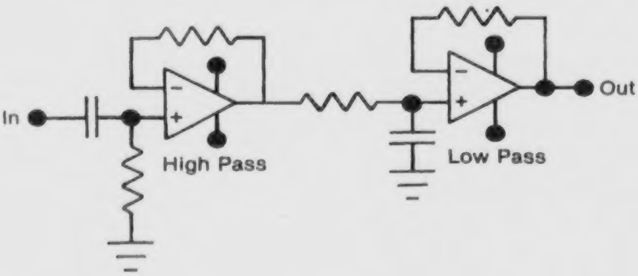
a. Low-pass active filter


C2
R1
Input
C1
Output
RB
RA

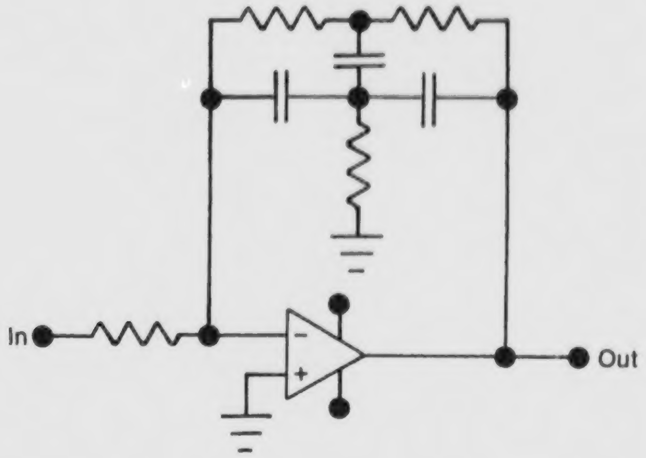
b. High-pass active filter


RF
Input
Output
R1
RB
RA

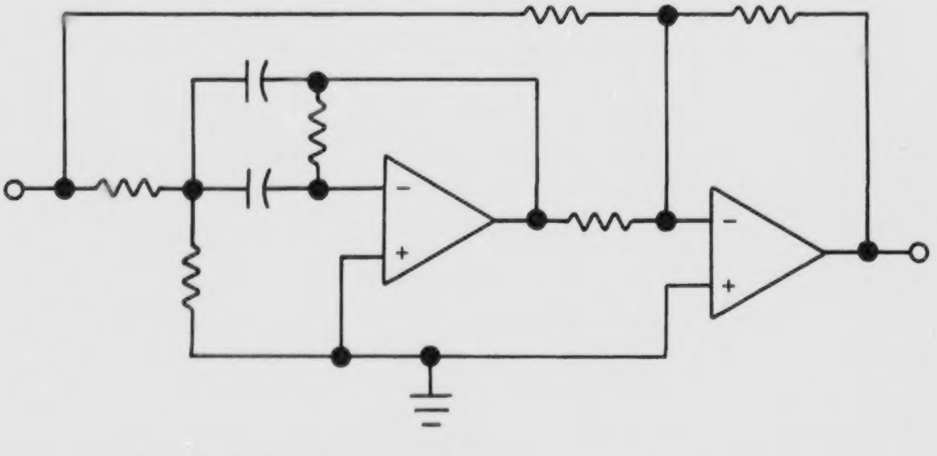
c. Band-pass active filter with dual op-amp branches


In
High Pass
Low Pass
Out

d. Band-pass active filter with dual RC branches



e. Notch active filter



35. **Characteristics of a transimpedance amplifier**

a. Voltage controlled

b. Consists of three stages like an op-amp

c. Does not have a fixed gain-bandwidth product

d. Very fast slew rate

Information Sheet

36. IC switches and control devices

Note: A switch is a device for opening or closing a circuit. The circuit may be electrical, or it may direct the flow of a gas, liquid, or other substance. The switch may open or close a single circuit path or it may allow the energy or substance to be directed along one of several paths. Controls are devices that are adjustable beyond the either-or state of on and off. Thus, a CD player may have a power switch that is either on or off and adjustable controls for volume, speaker balance, treble, and bass. Both switches and controls may be manually operated or automatically operated, usually with input from a sensor circuit. They may be actuated by mechanical, electrical, hydraulic, or other means. Electronic packages may be discrete devices or integrated circuits.

a. Switch—Opens or closes circuit

b. Control—Adjusts circuit flow over a defined range

37. IC timers

a. A timer may be used to control the start and duration of an operation.

Examples: A cycle on a washing machine, a traffic signal, snooze alarm

b. A timer may be used to measure the duration of an operation.

Examples: Radar return timer, elapsed-time meter, clock

c. Electronic timers use oscillators to trigger pulses to indicate the passing of time.

d. The oscillator may be internal or external to the timer.

e. The oscillator may be driven by a crystal, constant frequency signal, or other generator capable of producing a regularly recurring signal.

38. IC counters

a. Counters register the number of occurrences of an event.

Note: If you were to count the number of students in your class, your recognition of each different student can be defined as an event. Each time you recognize a different student, that event represents a student. If it occurs 18 times (and you have counted correctly), then there are 18 students in your class. Electronic counters work in much the same way because they generally do not actually count objects; they usually count signals that occur as the result of the presence of an object or energy form.

Information Sheet

b. A counter may recognize the event by the receipt of a signal.

Examples: The flow of gasoline at a service station pump, a Geiger counter

c. A counter may recognize the event by the failure to receive a signal.

Example: Photoelectric counter

d. A counter may be continuously cumulative, counting occurrences as long as it is operational.

Example: Electronic odometer

e. A counter may be manually resettable.

Example: Videotape footage counter

f. A counter may be self-resetting.

Example: Scaling circuit, scale-of-10 counter

g. A counter may monitor continuously.

h. A counter may monitor on a sampling basis, with samples taken at prescribed or random intervals or samples taken from larger collections of the substance or energy to be counted.

39. IC transmitters and receivers

Note: Signals carrying information are transmitted through several media or *message channels*: air, water, wires, fiber optic cables, the earth, and others. The signals may be purely electrical or any of various other forms, such as the light in a fiber optic cable, the infrared signal carrier of a television remote control, or an x-ray detector in an antenna dish trained on the stars. ICs are used in most of these circuits, which consist of three main components.

a. Transmitters—Condition the signal and insert it into the transmission medium

b. Receivers—Detect the signal and convert it for use at the receiving station

c. Transceivers—Both transmit and receive signals

Information Sheet

40. Operation and principles of an RF circuit

a. Energy can be transmitted from one place to another through the use of high frequency waves called *radio waves* or *radio frequencies* (RF).

b. The transmission begins as alternating current that is used to power an oscillator, whose output is routed to an antenna that converts the oscillations into radio waves.

c. The radio waves can be made to represent information through a process called *modulation* in which the signal containing the information (such as an audio or video signal) is combined with the oscillator signal to produce a modulated signal.

d. The signal's amplitude, frequency, or phase can be modulated.

e. The RF signal is called the *carrier*.

f. With amplitude modulation (AM), the bandwidth of the signal is one amplitude above and below the carrier frequency with these upper and lower frequencies being called *sidebands*.

Note: AM broadcasting can be done with one sideband eliminated to produce a single-sideband transmission.

g. With frequency modulation (FM), the carrier is called the *center frequency*, which modulates to a higher frequency when a positive amplitude is applied by the information signal and to a lower frequency when a negative amplitude is applied.

Note: As a result, FM signals can have an infinite number of sidebands so that in actual practice the signal is reduced to the significant sidebands. The number of significant sidebands is determined by the amount of difference between the carrier frequency and the frequency of the information signal at its peak voltage. This difference is referred to as *frequency deviation*.

h. When the radio waves strike a receiving antenna, a high frequency current is induced in the antenna that duplicates the broadcast signal.

i. The receiving antenna is connected to a tuned radio-frequency receiver that is set to detect signals within a given bandwidth and amplify the RF signals.

j. The RF signals are fed through a superheterodyne receiver, which contains an oscillator that generates an intermediate frequency (IF) and mixes it with the amplified RF signal.

Note: The combining of radio signals is called *heterodyning* or *mixing*. Many receivers consist of ICs that perform many of the functions described here.

k. The combined signal is routed through one or more IF amplifiers that filter the signal.

l. In FM reception, the signal then passes through a limiter to remove amplitude variations that would distort the output signal.

m. Next the signal passes through a detector that separates the information portion of the signal and sends it to the output amplifier.

Note: In FM systems, the detector is sometimes referred to as a *discriminator.*

n. In some systems, the detector may also feed signals to an automatic gain control (AGC) for AM systems or automatic frequency control (AFC) for FM systems that is fed back to the amplifiers (for AGC) or oscillator (for AFC) to maintain a more constant output volume.

Note: These feedback circuits are sometimes termed *automatic volume controls* (AVCs).

o. The output amplifier—typically an audio amplifier for radio broadcasts—strengthens the signal and routes it to the output devices, such as speakers.

41. Operation and principles of an IF circuit

a. The RF amplifiers and detector of a receiver circuit must be resonant with each other and provide an adequate bandwidth coverage in order to have good reception across the full range of broadcast frequencies.

b. These problems can be reduced by tuning the radio to a few fixed frequencies, which is not possible if a radio is to be capable of receiving any broadcast station.

c. A superheterodyne receiver overcomes these problems by using an oscillator to insert a signal of a fixed frequency that is added to the received signal in a mixer.

Note: The oscillator generally produces a signal that is equal to the sum of the received signal and a standard intermediate frequency (IF). Typical standard IFs include 455 kHz for AM, 262 kHz for some automotive AM, 10.7 MHz for FM, and 44 MHz for television. Thus, if a received signal is 1520 kHz with an IF of 455 kHz, the oscillator would insert a 1975 kHz signal (1520 + 455 = 1975).

d. The mixer outputs signals at four different frequencies: the received signal, the signal from the oscillator, a summed signal of the received signal and the oscillator signal, and a difference signal of the received signal minus the oscillator signal.

e. The difference signal will be equal to the IF value and will pass through the filters of the IF amplifiers to the detector.

f. It would be possible for another signal to pass through the receiver if the antenna picked up a signal on a frequency equal to the sum of the IF and the oscillator frequency in a kind of noise referred to as *image interference.*

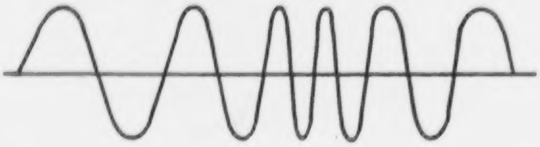
Note: Continuing with the above example, if the radio is tuned to 1520 kHz with a 455 kHz IF, the oscillator signal would be 1975 kHz. If the antenna then picked up a shortwave broadcast of 2430 kHz, the ouput of the mixer would include a 455 kHz when it subtracts the oscillator signal (1975 kHz) from the received signal (2430 kHz), which would go through the IF amplifiers and filters.

g. To eliminate image interference, many IF circuits insert two signals that can mix with the oscillator signal to produce the IF (one through summing and one through subtracting), with the first signal being the tuned frequency and the second being called the image frequency.

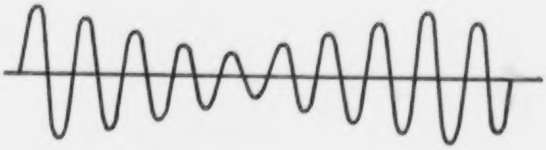
h. The IF circuit rejects the image frequency because it is outside the resonance of the tuned frequency.

42. Types of signal modulation

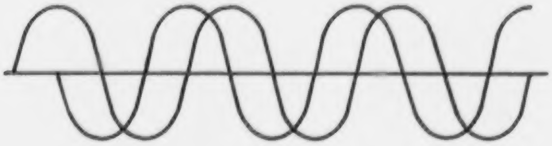
a. Frequency modulation



b. Amplitude modulation



c. Phase modulation



Information Sheet

43. Characteristics of microwaves

a. Microwaves are the part of the electromagnetic spectrum between 1 and 300 gigaHertz (GHz).

b. Microwaves are usually generated by an electron-tube UHF oscillator called a *klystron* or by another type of electron-tube oscillator called a *magnetron*.

Note: A klystron uses electric fields to concentrate an electron beam and feed it into a resonant cavity, while a magnetron uses the interaction of magnetic waves and electrical fields to direct electrons.

c. Some ICs are specifically designed to operate at microwave frequencies and are referred to as *microwave integrated circuits* (MICs).

d. Microwaves are normally transmitted through the air or through coaxial cable or specially constructed chambers called *waveguides*.

44. Uses of microwave circuits in electronic systems

a. UHF television broadcast

b. Satellite communications

c. Mobile radio communications

d. Cellular telephone communications

e. Telemetry

f. Radar systems

g. Microwave ovens

45. Parts of a fiber optic circuit

a. Light source—Generally a laser diode or LED that is part of a transmitter IC that includes circuitry for converting the source signal so that it can be amplitude modulated for transmission

b. Fiber optic cable—Glass or plastic core enclosed in optical cladding that refracts the light back into the core

c. Detector—Phototransistor or photodiode that is part of a receiver that converts the photo-sensitive device output signals back to its original format

Information Sheet

46. Characteristics of a fiber optic circuit

a. Use of light provides a very fast carrier.

b. The amount of information that can be transmitted in a given period of time is called *data rate* and is measured in *bauds* (bits per second).

c. The speed of light allows transmission of a very wide bandwidth, resulting in a high data rate.

d. Fiber-optics are not affected by electromagnetic interference.

e. Optical interference can be eliminated by an opaque covering of the fiber.

f. Transmission down the center of the cable is called *single-mode* propagation.

g. Transmission that relies on light being reflected off the cladding is called *multimode propagation.*

h. Loss of signal from light being absorbed by the cladding is called *attenuation.*

i. As the light travels through the cable in multimode propagation, the individual beams of light can travel different distances due to being refracted at varying numbers of times, leading to distortion of the signal as the pulses spread.

j. Both attenuation and pulse spreading limit the distances over which signals can be transmitted without serious distortion for a given data rate.

47. Operation of IC sensor devices

Note: A frequent use of IC devices is to detect the presence of a substance or of energy and often to measure the quantity of the substance or energy. In a practical circuit, the information from the sensor would then have to be converted into a form that is useful to the operator or to automatic monitoring equipment. For example, a digital thermometer circuit measures temperature and generates a display that a person can read while an electronic thermostat circuit senses temperature and turns equipment on or off as a result of changes in temperature.

a. A sensor circuit normally consists of a *sensor* to detect or measure a substance or energy and an *actuator* to initiate a response to the detection or measurement.

b. A sensor circuit may also contain *signal conditioning devices* to make the sensor output more usable.

c. A sensor circuit monitors an environment to which its input interface is exposed.

d. The sensor monitors for the presence or absence of a substance or energy or measures the quantity of a substance or energy.

e. The substance or energy that causes a response in the sensor is called a stimulus.

f. A sensor circuit can be either normally on or normally off.

g. In terms of its power output, a sensor may be *modulating*, meaning that it uses an auxiliary power source, or *generating*, meaning that it converts the input signal directly to power output.

h. The output signal is either analog or digital.

i. The operating mode of a sensor may be defined as *deflection mode*, where the sensor is at rest and the presence or absence of the stimulus causes a change (physical, chemical, electrical, etc.) in the sensor, or as *null mode*, in which the sensor generates a force to oppose the stimulus to try to maintain a steady state.

j. Sensors may also be classed according to what they sense or measure.

48. Types of IC sensor stimuli

Note: The list of stimuli that sensors can detect or measure is almost limitless. Those given below provide an overview of those you are most likely to encounter as an electronics technician.

a. Light

b. Sound

c. Humidity

d. Temperature

e. Flow

f. Particles in a gas or liquid

g. Radiation

h. Chemicals

i. Pressure, force, and torque

j. Position

Information Sheet

k. Speed and acceleration rate

l. Electrical characteristics

49. Photo-sensitive devices in linear circuits

a. Photoresistor—Device whose electrical resistance varies as a function of the amount of light applied to the device

b. Phototransistor—Device that generates electrical current when exposed to light and then processes that signal for amplification, oscillation, or switching

c. Photodiode—Device that conducts in one direction and whose conductivity varies in accordance with the amount of light that falls upon it

d. Photoelectric cell—Device that converts light into electricity

Note: The term *photoelectric cell* is used in both a general and specific way. The phrase is sometimes applied to any device that produces electricity from light, which would include phototransistors, or to devices that change in electrical resistance when exposed to light, which would include photodiodes.

e. Photovoltaic cell—Device that converts light into electricity specifically as a power source

f. Photoelectric counter—Device that counts objects as a result of their breaking a beam of light

g. Light-activated SCR—Device that acts as both a photosensor and a switch so that currents can be switched on by means of a light signal

h. Light-activated SCS—Device that functions as both a photoelectric cell and a switch

50. Signal processing functions

Note: This objective lists signal characteristics that may be conditioned by ICs. In some cases, one discrete component can be used to perform the same function, such as using a diode to rectify a signal or a single transistor to amplify it. However, such functions can be performed by ICs, and in most electronic equipment many of the transistors, diodes, and similar components are embedded in ICs. The items listed are common characteristics that are modified between input devices, such as receivers, computer keyboards, and sensors, and output devices, such as loudspeakers, computer monitors, and actuators.

a. Amplitude—The distance that the signal fluctuates above and below a prescribed value (usually 0) is increased or decreased

Information Sheet

b. Frequency—The rate at which a fluctuating signal's timing is increased or decreased

c. Phasing—A given point in the waveform of the output signal, such as its peak, is shifted from the corresponding point of the input signal

Example: Inverting amplifier

d. Waveform shape—The general form of the output signal is different from that of the input signal

Examples: Square wave is changed to sawtooth wave, a wave is clipped

e. Power gain—The wattage of the output signal is different than that of the input signal

f. Voltage gain—The voltage of the output signal is different than that of the input signal

g. Current gain—The amperage of the output signal is different than that of the input signal

h. Direct versus alternating current—The signal is rectified or oscillated

i. Digital versus analog—The signal is changed from one that varies between discrete values to one that varies in a continuous fashion or from one that varies in a continuous fashion to one that varies between discrete values

j. Signal-to-noise ratio—The percent of signal voltage that is usable compared to that that is not usable is changed (usually reduced)

k. Arithmetic functions—The output signal compares to the input signal in a way that can be mathematically defined

Examples: Integrator and differentiator amplifiers

l. Digital coding—The method of presenting the signal values in a numerical representation changes from one system to another

Example: Changing from binary coding to hexadecimal coding

m. Logic combinations—The output signal compares to the input signal in a way that can be described by a logic statement

Example: A signal is routed through an AND gate

Linear Integrated Devices and Circuits
Unit 2

Assignment Sheet 1—Calculate the Closed-Loop Gain for an Inverting and a Noninverting Amplifier

Name ______________________________ Overall Rating ____________

Evaluation criteria	**Rating**
• Directions have been followed	________
• Minimum of 80 percent of answers are correct	________

Note: Each correct answer is worth 10 points.

Introduction: In the previous unit, you learned how to calculate the gain in transistor amplifiers. In this unit, you have studied op-amps. Gain in op-amps represents the same characteristic that it does in transistor amplifiers: the ratio between a characteristic of the input signal—such as voltage, current, or power—and that same characteristic in the output signal. However, most op-amp circuits use feedback, which changes the input values, making it necessary to address feedback in our calculations.

Before we look at the equations for calculating gain, there are a couple of characteristics that need to be considered. First, the voltages and currents in electronic circuits that are routed through op-amps are near 0. Recognizing this will help you understand some of the equations presented here. For example, let's look at a noninverting op-amp. The feedback circuit and input resistor form a voltage divider, which allows us to express the relationship between V_{in} and V_{out} as

$$V_{in} = V_{out} \times \frac{R_i}{R_i + R_f}$$

Because voltage gain is the ratio between V_{in} and V_{out}, we can express the noninverting op-amp's voltage gain ratio as

$$A_v = \frac{V_{out}}{V_{in}} = \frac{V_{out}}{V_{out} \times \frac{R_i}{R_i + R_f}} = \frac{1}{\frac{R_i}{R_i + R_f}} = 1 \times \frac{R_i + R_f}{R_i} = \frac{R_i}{R_i} + \frac{R_f}{R_i} = 1 + \frac{R_f}{R_i}$$

Assignment Sheet 1

So in a noninverting op-amp circuit where the feedback resistor is 50 Kohms and the input resistor is 10 Kohms, the voltage gain would be

$$A_V = 1 + \frac{R_f}{R_i} = 1 + \frac{50 \text{ Kohms}}{10 \text{ Kohms}} = 1 + 5 = 6$$

If either the input or output voltage is known, then the other can be calculated by rearranging the voltage gain equation. If the input voltage of the previous example were -0.5 VDC, then the output voltage can be calculated as

$$V_{out} = A_V \times V_{in} = 6 \times -0.5 \text{ VDC} = -3 \text{ VDC}$$

The same principles can be applied for determining the gain of an inverting op-amp, if we account for the difference in circuitry. With an inverting op-amp, the feedback and input currents are both fed into the op-amp's inverting terminal. Thus, we have two input currents—the actual input current and the feedback current. The noninverting terminal is grounded, which means that we can assume that the inverting terminal is at ground potential (based on the assumption that there is no significant difference in potential between the two terminals due to their small values). Consequently, the feedback signal is also at ground potential, and the point where the feedback circuit connects to the input circuit is called a *virtual ground*. By applying Ohm's Law, the input and feedback currents can be expressed as

$$V_{in} = I_{in} \times R_i \qquad \text{and} \qquad -V_{out} = I_f \times R_f \qquad \text{or} \qquad V_{out} = I_f \times (-R_f)$$

Note that the equation for feedback uses a negative value for the output voltage due to the inversion of the op-amp. If we substitute these expressions in the formula for voltage gain, we get

$$A_v = \frac{V_{out}}{V_{in}} = \frac{I_f \times (-R_f)}{I_{in} \times R_i} = -\frac{R_f}{R_i}$$

Thus, if we have an inverting op-amp with a 50-Kohm feedback resistor and a 10-Kohm input resistor, the gain should be

$$A_v = -\frac{R_f}{R_i} = -\frac{50 \text{ Kohms}}{10 \text{ Kohms}} = -5$$

The minus sign on the gain values does not represent a reduction as the minus sign did on a decibel value for transistor amplifiers. It simply means that the voltage is inverted. Thus, an AC output would be 180° out-of-phase from the input signal and that a DC output would have the opposite polarity of the input signal. For example, in the circuit just described, if the input is -0.5 VDC, the output will be +2.5 VDC (-5 x [-0.5 VDC]).

In this assignment sheet, you will apply the equations just presented to calculate gain and voltage for inverting and noninverting op-amps.

Assignment Sheet 1

Directions: Study the schematics below and then answer the questions that follow. Write your answers on the blanks provided below each question.

Figure A

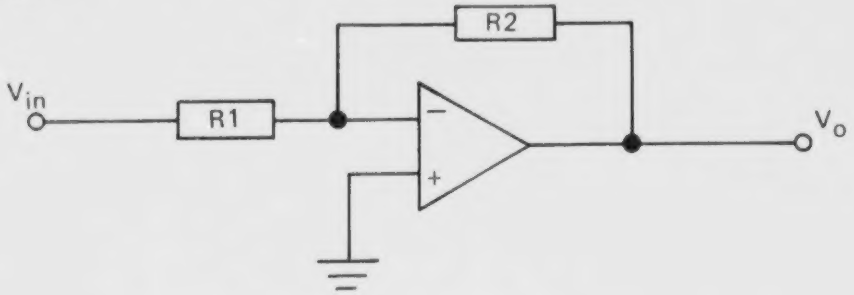
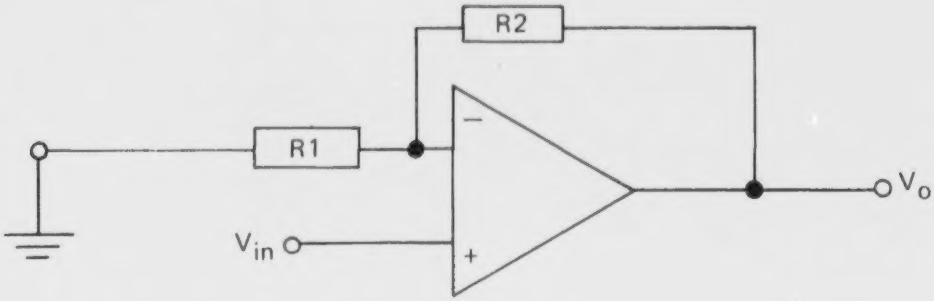


Figure B



Note: Questions 1-5 refer to Figure A.

1. What is the voltage gain for this circuit if R1 equals 10 Kohms and R2 equals 100 Kohms?

____

2. What is the output voltage for the circuit in Question 1 if the input voltage is +5 VDC?

____

Assignment Sheet 1

3. What is the voltage gain for this circuit if R1 equals 20 Kohms and R2 equals 1 Mohm?

____

4. What is the output voltage for the circuit in Question 3 if the input voltage is -0.4 volts?

____

5. What is the voltage gain for this circuit if R1 equals 1 Kohms and R2 equals 30 Kohms?

____

Note: Questions 6-10 refer to Figure B.

6. What is the voltage gain for this circuit if R1 equals 10 Kohms and R2 equals 80 Kohms?

____

7. What is the output voltage for the circuit in Question 6 if the input voltage is 0.2 volts?

____

8. What is the voltage gain for this circuit if R1 equals 800 ohms and R2 equals 100 Kohms?

____

9. What is the output voltage for the circuit in Question 8 if the input voltage is 4 millivolts?

____

10. What is the voltage gain for this circuit if R1 equals 15 Kohms and R2 equals 300 Kohms?

____

Linear Integrated Devices and Circuits
Unit 2

Assignment Sheet 2—Calculate the Output Voltage of a DC Summing Amplifier

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
• Directions have been followed	________
• Minimum of 80 percent of answers are correct	________
Note: Each correct answer is worth 10 points.	

Introduction: Calculating the output voltage of a summing amplifier is similar to calculating the output voltage of a single-input op-amp, except that the total effect of the additional inputs must be addressed. This effect is different depending on whether an inverting or noninverting configuration is used. Let's look at the inverting summing amplifier first.

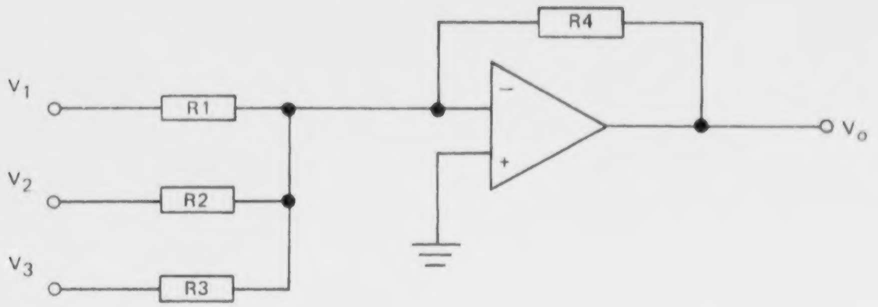
For a single-input op-amp, output voltage can be calculated by rearranging the formula for gain and then substituting equivalent values in this way:

$$V_{out} = A_V \times V_{in} = -\frac{R_f}{R_i} \times V_{in}$$

Thus, the input voltage for each input branch can be computed and then totaled using the equation

$$V_{out\text{-}t} = V_{out\text{-}1} + V_{out\text{-}2} + \ldots V_{out\text{-}n}$$

In the circuit below, three inputs are used. Recall that the connection between the inputs and the feedback circuit serves as a virtual ground, making the potential of each input the same.



Assignment Sheet 2

If the input resistor has a value of 1 Kohm and the feedback resistor is 3 Kohms, while the input voltages are 1, 2, and 3 volts respectively, then the total output would equal

$$V_{out\text{-}t} = \left(1 \text{ volt} \times \left[-\frac{3 \text{ Kohms}}{1 \text{ Kohm}}\right]\right) + \left(2 \text{ volts} \times \left[-\frac{3 \text{ Kohms}}{1 \text{ Kohm}}\right]\right) + \left(3 \text{ volts} \times \left[-\frac{3 \text{ Kohms}}{1 \text{ Kohm}}\right]\right)$$

$$= (1 \text{ volt} \times [-3]) + (2 \text{ volts} \times [-3]) + (3 \text{ volts} \times [-3])$$

$$= (-3 \text{ volts}) + (-6 \text{ volts}) + (-9 \text{ volts})$$

$$= -18 \text{ volts}$$

If we consider a noninverting circuit, the difference is that the feedback voltage does not affect the input values directly but it does affect gain. The effect of gain is computed by the equation for voltage gain that you studied in the previous assignment sheet rearranging it for V_{out}:

$$V_{out} = V_{in} \times A_V = V_{in} \times (1 + \frac{R_f}{R_i})$$

As with the inverting op-amp, the total input for the noninverting summing amplifier is equal to the sum of each of the individual inputs, so that this total ($V_{in\text{-}t}$) can be substituted for V_{in} in the equation. Thus, a circuit with a 2-volt input and a 4-volt input with an inverting terminal resistor value of 3 Kohm and a feedback resistor value of 12 Kohm would have an output voltage of

$$V_{out} = V_{in\text{-}t} \times (1 + \frac{R_f}{R_i})$$

$$= (2 \text{ volts} + 4 \text{ volts}) \times (1 + \frac{12 \text{ Kohms}}{3 \text{ Kohms}})$$

$$= 6 \text{ volts} \times (1 + 4)$$

$$= 6 \text{ volts} \times 5$$

$$= 30 \text{ volts}$$

In this assignment sheet, you will calculate values in summing amplifiers.

Directions: Study the schematics on the next page and then solve for the output voltage for the questions that follow. Each question defines the input voltages and resistor values for the circuit. Write your answers in the spaces provided.

Assignment Sheet 2

Figure A

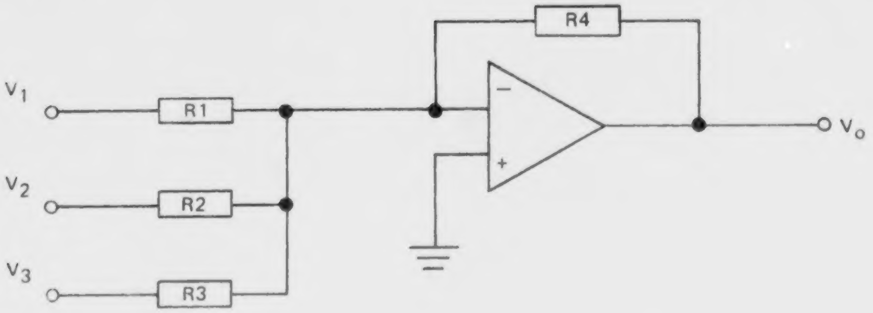
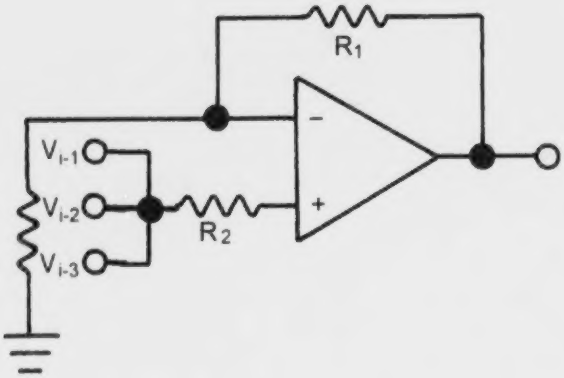

R4
V1
R1
V2
R2
V3
R3
−
+
Vo

Figure B


R1
−
+
Vi-1
Vi-2
Vi-3
R2

Note: Questions 1-5 refer to Figure A.

1. R1 = 10 Kohms
   R2 = 5 Kohms
   R3 = 10 Kohms
   R4 = 10 Kohms

   V_{i-1} = +5 VDC
   V_{i-2} = +2 VDC
   V_{i-3} = +1 VDC

   ____

2. R1 = 10 Kohms
   R2 = 5 Kohms
   R3 = 5 Kohms
   R4 = 10 Kohms

   V_{i-1} = +6 VDC
   V_{i-2} = +4 VDC
   V_{i-3} = +2 VDC

   ____

Assignment Sheet 2

3. R1 = 10 Kohms
R2 = 15 Kohms
R3 = 10 Kohms
R4 = 20 Kohms

V_{i-1} = -5 VDC
V_{i-2} = +3 VDC
V_{i-3} = +2 VDC

____

4. R1 = 5 Kohms
R2 = 5 Kohms
R3 = 10 Kohms
R4 = 20 Kohms

V_{i-1} = -4 VDC
V_{i-2} = -4 VDC
V_{i-3} = -4 VDC

____

5. R1 = 10 Kohms
R2 = 5 Kohms
R3 = 10 Kohms
R4 = 10 Kohms

V_{i-1} = +0.5 VDC
V_{i-2} = +0.2 VDC
V_{i-3} = +1 VDC

____

Note: Questions 6-10 refer to Figure B.

6. R1 = 10 Kohms
R2 = 5 Kohms

V_{i-1} = +9 VDC
V_{i-2} = +2 VDC
V_{i-3} = +4 VDC

____

7. R1 = 5 Kohms
R2 = 5 Kohms

V_{i-1} = +5 VDC
V_{i-2} = +2 VDC
V_{i-3} = +1 VDC

____

Assignment Sheet 2

8. R1 = 10 Kohms
R2 = 5 Kohms

V_{i-1} = -5 VDC
V_{i-2} = +6 VDC
V_{i-3} = -6 VDC

____

9. R1 = 10 Kohms
R2 = 20 Kohms

V_{i-1} = -2 VDC
V_{i-2} = +2 VDC
V_{i-3} = +1 VDC

____

10. R1 = 15 Kohms
R2 = 5 Kohms

V_{i-1} = +0.5 VDC
V_{i-2} = +0.2 VDC
V_{i-3} = +0.1 VDC

____

Linear Integrated Devices and Circuits
Unit 2

Assignment Sheet 3—Determine Specifications for Commercially Available Op-Amps

Name ______________________________ Overall Rating ____________

Evaluation criteria	Rating
• Directions have been followed	________
• Minimum of 80 percent of answers are correct	________
• Student made correct interpretations of data	________
• Student recognizes value of data obtained	________
• Student effectively communicated information	________

Note: Each correct answer is worth 10 points.

Introduction: For an electronics technician to be able to recognize whether a circuit is operating correctly and whether test readings are acceptable, she or he must be able to determine what those readings should be. For most components, including op-amps, information regarding key characteristics are available on data sheets and in handbooks. In this assignment sheet, you will determine critical information about an assigned op-amp.

Directions: Discuss with your instructor which op-amp you will be assigned. Using resources available in your facility, answer the following questions about the assigned op-amp. Write your answers in the spaces provided.

1. What is the component part number? ____________________
2. Who is the manufacturer? ____________________
3. In what packages is it available?

   ____
4. What is the V_{CC} power supply voltage? ____________________
5. What is the operating temperature range? ____________________
6. What is the input resistance? ____________________

Assignment Sheet 3

7. What is the voltage gain? ____________________

8. What is the common mode rejection ratio? ____________________

9. What is the output voltage swing? ____________________

10. For what uses is this device best suited?

____

____

____

____

Linear Integrated Devices and Circuits
Unit 2

Job Sheet 1—Construct and Test an Inverting Amplifier

Name ______________________ Attempt Number __________

Date ______________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedures were done correctly	________
• Equipment was properly connected and operated	________
• Measurements were accurate	________
• Student demonstrated an understanding of the applicable principles	________

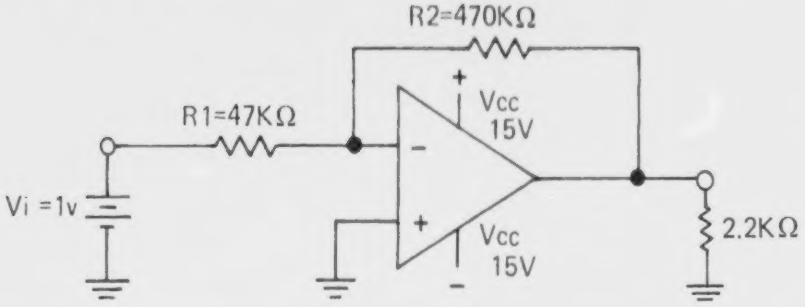
Introduction: Op-amps are one of the most common ICs in use in electronics equipment today. The technician who understands how op-amps operate and who can effectively troubleshoot op-amp circuits will find plenty of work to do. This is the first of a series of job sheets that will further acquaint you with the construction of op-amp circuits and their functioning.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A Equipment and materials

- Multimeter
- Dual-trace Oscilloscope
- Sine wave generator
- Test leads
- Variable DC power supply, regulated
- DC power supply, ±15 volts or dual tracking
- LM741 op-amp, or equivalent
- 470 Kohm resistor, ¼-watt
- 47 Kohm resistor, ¼-watt
- 2.2 Kohm resistor, ¼-watt
- Conductor
- Mounting surface and hardware
- Pencil and paper
- Table at end of job sheet
- Circuit drawing on the next page

Job Sheet 1



B. Procedure

☐ 1. Assemble the circuit per drawing, but do **not** apply power.

☐ 2. Calculate the voltage gain and record it in the table.

☐ 3. Calculate the output voltage across the load resistor and record in the table.

☐ 4. Energize the op-amp.

☐ 5. Apply a 1 VDC signal to the input connection.

☐ 6. Measure and record the input voltage, including polarity.

☐ 7. Measure and record the output voltage, including polarity.

☐ 8. Turn off the DC power supply and remove it from the circuit input.

☐ 9. Connect the sine wave generator to the circuit input.

☐ 10. Apply a 1.5-volt peak-to-peak sine wave to the circuit input.

☐ 11. Calculate the output voltage and record it in the table.

☐ 12. Use the oscilloscope to measure the input signal and record the value.

☐ 13. Use the oscilloscope to measure the output signal and record the value.

☐ 14. Remove power from the circuit.

☐ 15. Use the values obtained at Steps 6 and 7 to calculate the voltage gain.

☐ 16. Use the values obtained at Steps 11 and 12 to calculate the voltage gain.

Job Sheet 1

☐ 17. Discuss your results with your instructor; be prepared to discuss the following points:

- How does your gain calculation compare with the value calculated from the multimeter measurements?
- How does your gain calculation compare with the value calculated from the oscilloscope measurements?
- What would account for the differences if any?
- Was inversion evident in both the DC signal and the sine wave? Why or why not?
- If a larger resistor were used in R2, would you expect the gain to increase or decrease? Why?

☐ 18. Disassemble circuit and return equipment and materials to their proper storage location.

Evaluator's comments: ____

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Job Sheet 1

Characteristic	Measured Value	Calculated/Expected Value
Voltage gain		
DC voltage input		
DC voltage output		
A_V calculated from DC measurements		
Sine wave voltage input		
Sine wave voltage output		
A_V calculated from oscilloscope measurements		

Linear Integrated Devices and Circuits
Unit 2

Job Sheet 2— Construct and Test a Noninverting Amplifier

Name______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedures were done correctly	________
• Equipment was properly connected and operated	________
• Measurements were accurate	________
• Student demonstrated an understanding of the applicable principles	________

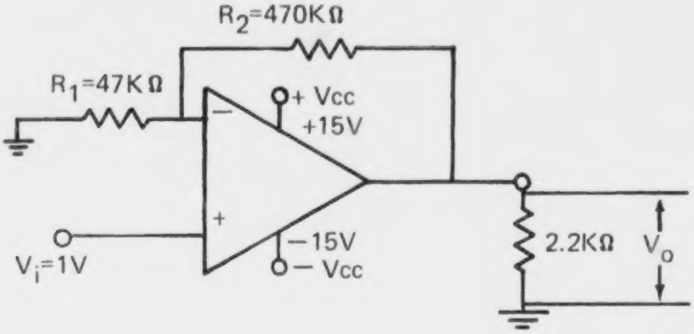
Introduction: While the inverting op-amp circuit is used more often than the noninverting configuration, the latter can be found in many electronic applications, especially in circuits where it is important to maintain DC polarity or AC phasing. The procedure in this job sheet is essentially the same as that in Job Sheet 1, except that you will build and test a noninverting amplifier in this project. Based on your studies and your observations in the previous job sheet, what types of differences can you expect to see when using a noninverting configuration?

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Multimeter
- Dual-trace Oscilloscope
- Sine wave generator
- Test leads
- Variable DC power supply, regulated
- DC power supply, ±15 volts or dual tracking
- LM741 op-amp, or equivalent
- 470 Kohm resistor, ¼-watt
- 47 Kohm resistor, ¼-watt
- 2.2 Kohm resistor, ¼-watt
- Conductor
- Mounting surface and hardware
- Pencil and paper
- Table at end of job sheet
- Circuit drawing on the next page

Job Sheet 2



B. Procedure

☐ 1. Assemble the circuit per drawing, but do **not** apply power.

☐ 2. Calculate the voltage gain and record it in the table.

☐ 3. Calculate the output voltage across the load resistor and record in the table.

☐ 4. Energize the op-amp.

☐ 5. Apply a 1 VDC signal to the input connection.

☐ 6. Measure and record the input voltage, including polarity.

☐ 7. Measure and record the output voltage, including polarity.

☐ 8. Turn off the DC power supply and remove it from the circuit input.

☐ 9. Connect the sine wave generator to the circuit input.

☐ 10. Apply a 1.5-volt peak-to-peak sine wave to the circuit input.

☐ 11. Calculate the output voltage and record it in the table.

☐ 12. Use the oscilloscope to measure the input signal and record the value.

☐ 13. Use the oscilloscope to measure the output signal and record the value.

☐ 14. Remove power from the circuit.

☐ 15. Use the values obtained at Steps 6 and 7 to calculate the voltage gain.

Job Sheet 2

☐ 16. Use the values obtained at Steps 11 and 12 to calculate the voltage gain.

☐ 17. Discuss your results with your instructor; be prepared to discuss the following points:

- How does your gain calculation compare with the value calculated from the multimeter measurements?
- How does your gain calculation compare with the value calculated from the oscilloscope measurements?
- What would account for the differences if any?
- Was inversion evident in either the DC signal or the sine wave? Why or why not?
- If a larger resistor were used in R2, would you expect the gain to increase or decrease? Why?

☐ 18. Disassemble circuit and return equipment and materials to their proper storage location.

Evaluator's comments: ____

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Job Sheet 2

Characteristic	Measured Value	Calculated/Expected Value
Voltage gain		
DC voltage input		
DC voltage output		
A_V calculated from DC measurements		
Sine wave voltage input		
Sine wave voltage output		
A_V calculated from oscilloscope measurements		

Linear Integrated Devices and Circuits
Unit 2

Job Sheet 3— Construct and Test a Differential Amplifier

Name____ Attempt Number __________

Date ____ Overall Rating ____________

Evaluation criteria	**Rating**
• Procedures were done correctly	________
• Equipment was properly connected and operated	________
• Measurements were accurate	________
• Student demonstrated an understanding of the applicable principles	________

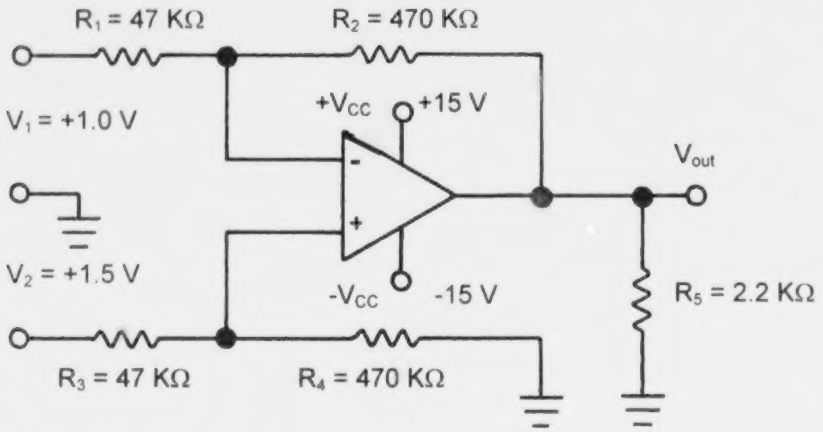
Introduction: Differential amplifiers are designed to respond to the differences between two input signals and are frequently built using op-amps. One way in which they differ from the amplifiers with which you have worked so far is that the input circuits are somewhat more complex to provide dual inputs. But the need for more circuit options also means that there are many design variables in differential amplifiers. In this job sheet, you will build and test a representative configuration.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Multimeter
- Test leads
- DC power supply, ±15 volts or dual tracking
- Two DC power supplies, variable
- LM741 op-amp, or equivalent
- Two 470 Kohm resistors, ¼-watt
- Two 47 Kohm resistors, ¼-watt
- 2.2 Kohm resistor, ¼-watt
- Conductor
- Mounting surface and hardware
- Pencil and paper
- Table at end of job sheet
- Circuit drawing on the next page

Job Sheet 3


$R_1 = 47\ K\Omega$
$R_2 = 470\ K\Omega$
$V_1 = +1.0\ V$
$+V_{CC}$
+15 V
-
+
V_{out}
$V_2 = +1.5\ V$
$-V_{CC}$
-15 V
$R_5 = 2.2\ K\Omega$
$R_3 = 47\ K\Omega$
$R_4 = 470\ K\Omega$

B. Procedure

☐ 1. Assemble the circuit per drawing, but do **not** apply power.

☐ 2. Calculate the output voltage across the load resistor and record in the table.

☐ 3. Energize the op-amp.

☐ 4. Apply 1.0 VDC to the input for V_1.

☐ 5. Apply 1.5 VDC to the input for V_2.

☐ 6. Measure and record the input voltage, including polarity, for V_1.

☐ 7. Measure and record the output voltage, including polarity, for V_1.

☐ 8. Repeat Steps 6 and 7 for V_2.

☐ 9. Adjust input signal at V_2 to 1.0 VDC.

☐ 10. Repeat Steps 6 and 7 for V_2.

☐ 11. Remove power from the circuit.

☐ 12. Calculate the difference mode gain, using the formula

$$A_D = \frac{V_{out}}{V_2 - V_1}$$

Note: The *difference mode gain* is the gain exhibited when the two input values differ from each other.

Job Sheet 3

☐ 13. Calculate the common mode gain, using the formula

$$A_C = \frac{V_{out}}{V_2}$$

Note: The *common mode gain* is the gain exhibited when the two input values are the same.

☐ 14. Discuss your results with your instructor; be prepared to discuss the following points:

- How does your output voltage calculation compare with the output value measurements?
- Do the results indicate that the differential amplifier is operating as it should? If not, what are some possible explanations?
- What is the difference in gain between in the common mode and the difference mode?
- What would be the effect if the two input resistors had different values from each other? If R2 and R4 were different?

☐ 15. Disassemble circuit and return equipment and materials to their proper storage location.

Evaluator's comments: ______________________________

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Job Sheet 3

Characteristic	**Calculated**	**Measured**
$V_1 = 1.0$, $V_2 = 1.5$	▨	▨
V_1	▨	
V_2	▨	
Output		
Gain		▨
$V_1 = 1.0$, $V_2 = 1.0$	▨	▨
V_1	▨	
V_2	▨	
Output		
Gain		▨

Linear Integrated Devices and Circuits
Unit 2

Job Sheet 4— Construct and Test a DC Summing Amplifier

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedures were done correctly	________
• Equipment was properly connected and operated	________
• Measurements were accurate	________
• Student demonstrated an understanding of the applicable principles	________

Introduction: The final amplifier circuit that we will work with in this series of job sheets is the summing amplifier. A summing amplifier accepts two or more inputs and combines them. Summing amplifiers are quite common in concert halls, recording studios, and other places where the input of several microphones are combined or *mixed* to produce a single output. Summing amplifiers may be inverting or noninverting. While inverting configurations are more common, noninverting versions are used in many summing circuits, especially where polarity is a concern.

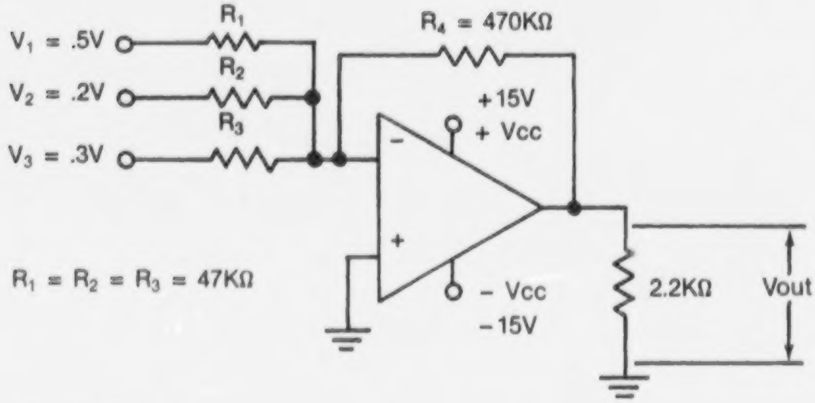
Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A Equipment and materials

- Multimeter
- Dual-trace oscilloscope
- Sine wave generator
- Test leads
- Variable DC power supply, regulated
- DC power supply, ±15 volts or dual tracking
- LM741 op-amp, or equivalent
- 470 Kohm resistor, ¼-watt
- Three 47 Kohm resistors, ¼-watt
- 2.2 Kohm resistor, ¼-watt
- Conductor
- Mounting surface and hardware
- Pencil and paper
- Table at end of job sheet

Job Sheet 4

- Circuit drawing



B. Procedure

☐ 1. Assemble the circuit per drawing, but do **not** apply power.

☐ 2. Calculate the output voltage across the load resistor and record in the table.

☐ 3. Energize the op-amp.

☐ 4. Apply the specified voltages to the input connections for V_1.

Note: If you are not able to obtain the required voltages, talk to your instructor about adding a voltage divider to the circuit.

☐ 5. Measure and record the input voltage, including polarity, for V_1.

☐ 6. Measure and record the output voltage, including polarity, for V_1.

☐ 7. Repeat Steps 4-6 for V_2 and V_1.

☐ 8. Repeat Steps 5 and 6 for V_3, V_2, and V_1.

☐ 9. Remove power from the circuit.

☐ 10. Discuss your results with your instructor; be prepared to discuss the following points:

- How does your gain calculation compare with the output value measurements?
- Do the results indicate that the summing amplifier is operating as it should? If not, what are some possible explanations?

Job Sheet 4

- What would be the effect on the results if the three input resistors and the feedback resistor all had the same value?
- What would be the effect if the three input resistors had different values from each other?

☐ 11. Disassemble circuit and return equipment and materials to their proper storage location.

Evaluator's comments: ______________________________

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Job Sheet 4

Characteristic	Measured Value	Calculated/Expected Value
DC voltage input for V_1		
DC voltage output for V_1		
DC voltage input for V_1 and V_2		
DC voltage output for V_1 and V_2		
DC voltage input for V_1, V_2, and V_3		
DC voltage output for V_1, V_2, and V_3		

Linear Integrated Devices and Circuits
Unit 2

Job Sheet 5—Construct and Test a Hartley Oscillator Using an Op-amp

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedures were done correctly	________
• Equipment was properly connected and operated	________
• Measurements were accurate	________
• Student demonstrated an understanding of the applicable principles	________

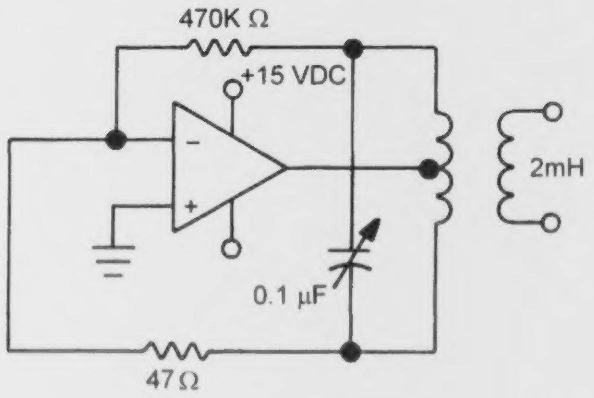
Introduction: In this unit, you have studied op-amp configurations of oscillator circuits that you built in the previous unit. This job sheet leads you through the construction and testing of a Hartley oscillator using an op-amp instead of transistors. The circuits function in much the same way. Each uses a tank circuit and produces a repetitive signal. But there are differences. As you complete this project, consider what the advantages and disadvantages are of each configuration of Hartley oscillator.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- RF transformer, 2 mH
- Regulated power supply, 0-25 VDC
- Oscilloscope
- Frequency counter (optional)
- Test leads
- LM741 op-amp, or equivalent
- 470 Kohm resistor, ¼-watt
- 47 Kohm resistor, ¼-watt
- 0.1 µF variable capacitor, 50 volts
- Low-voltage conductor
- Mounting surface and hardware
- Pencil and paper
- Circuit drawing

Job Sheet 5



B. Procedure

☐ 1. Assemble the circuit per drawing, but do **not** apply power.

☐ 2. Connect the oscilloscope to the output winding of the RF transformer.

☐ 3. Have your instructor check your circuit.

☐ 4. Energize the circuit and the power supply to 15 volts.

☐ 5. Observe the waveform and sketch it.

☐ 6. Adjust the variable capacitor up and down and observe the changes in waveform frequency.

☐ 7. Adjust the waveform to the lowest frequency obtainable.

☐ 8. Measure and record the peak-to-peak voltage.

☐ 9. Sketch the waveform and record the frequency.

☐ 10. Adjust the waveform to the highest frequency obtainable.

☐ 11. Measure and record the peak-to-peak voltage.

☐ 12. Sketch the waveform and record the frequency.

☐ 13. Continue operating the circuit at the highest obtainable frequency, place your finger lightly against the case of the op-amp, and observe any changes in the waveform that may result from the heating from your finger.

☐ 14. Turn off power to the circuit.

Job Sheet 5

☐ 15. Discuss your results with your instructor; be prepared to discuss the following points:

- What is the purpose of each portion of the circuit?
- What causes the oscillation?
- What were the lowest and highest frequencies at which you could obtain a stable waveform?
- What was the effect of heat on the circuit? Did the highest frequency increase or decrease as the circuit got warmer?
- Was there much difference in the performance of this circuit compared with the Hartley oscillator that you built using transistors in Unit 1? Which do you think is a better oscillator and why?

☐ 16. Disassemble circuit and return equipment and materials to their proper storage area.

Evaluator's comments: ______________________________

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Linear Integrated Devices and Circuits
Unit 2

Job Sheet 6— Construct and Test a Low-Pass Active Filter

Name______________________________ Attempt Number __________

Date ______________________________ Overall Rating ___________

Evaluation criteria	**Rating**
• Procedures were done correctly	________
• Equipment was properly connected and operated	________
• Measurements were accurate	________
• Student demonstrated an understanding of the applicable principles	________

Introduction: Another circuit that you have studied previously that can be built with an op-amp is the filter circuit. You should recall that filters are used to block some frequencies of signals and to allow other frequencies to pass through the circuit. One type of filter that you studied is the low-pass filter, which allows low frequency signals to pass through it. The chief advantage of using an op-amp to build the filter as opposed to those whose primary components are resistors, capacitors, and inductors is that feedback from the op-amp can be used to improve filter performance. In this job sheet, you will build and test a low-pass active filter using an op-amp.

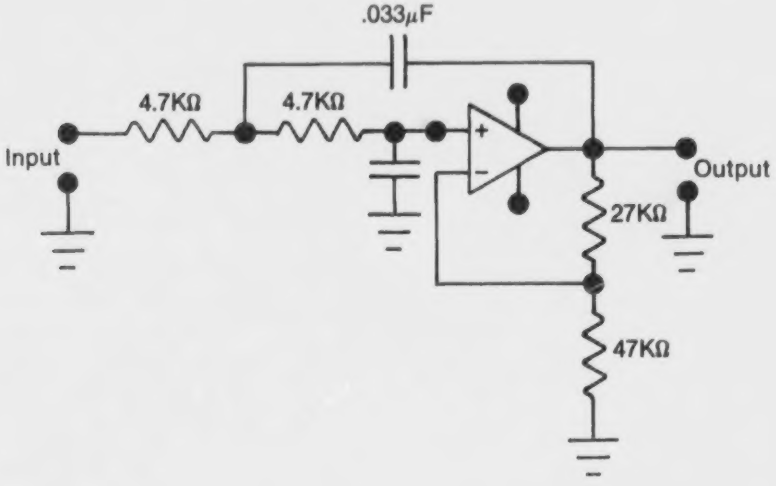
Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Sine wave generator
- Dual-trace oscilloscope
- Test leads
- DC power supply, -12 volts dual voltage
- LM741 op-amp, or equivalent
- 47 Kohm resistor, ¼-watt
- Two 4.7 Kohm resistors, ¼-watt
- 27 Kohm resistor, ¼-watt
- Two 0.033 μF capacitors
- Conductor
- Mounting surface and hardware

Job Sheet 6

- Pencil and paper
- Table at end of job sheet
- Graph grid at end of job sheet
- Circuit drawing



B. Procedure

☐ 1. Assemble the circuit per drawing, but do **not** apply power.

☐ 2. Connect the sine wave generator to the filter inputs.

☐ 3. Energize the circuit.

☐ 4. Apply a 100 Hz, 2-volts peak-to-peak signal to the input.

☐ 5. Measure and record the output signal peak-to-peak amplitude.

☐ 6. Repeat Steps 4-6 for each frequency listed in the table.

☐ 7. Remove power from the circuit.

☐ 8. Calculate the voltage gain ratio for each frequency.

☐ 9. Calculate the decibel voltage gain for each frequency.

☐ 10. Graph the gain in decibels versus frequency response curve for the circuit.

Job Sheet 6

☐ 12. Discuss your results with your instructor; be prepared to discuss the following points:

- What happens to gain as the input frequencies continue to increase?
- A filter's *cutoff point* is considered to be the point where gain reaches 70.7 percent of maximum gain or drops 3 dB from maximum gain. At what frequency does this occur in your circuit?
- Consider a passive filter with a similar cutoff point. What would it be like in terms of components, size, power consumption, etc.? What are the advantages and disadvantages of the two types of filters?
- What changes would have to be made to the circuit to make it a high-pass filter? A band-pass filter?
- If you wanted to make the cutoff slope steeper (closer to vertical), what could be done with this circuit to produce a sharper drop in gain?

☐ 13. Disassemble circuit and return equipment and materials to their proper storage location.

Evaluator's comments: ____

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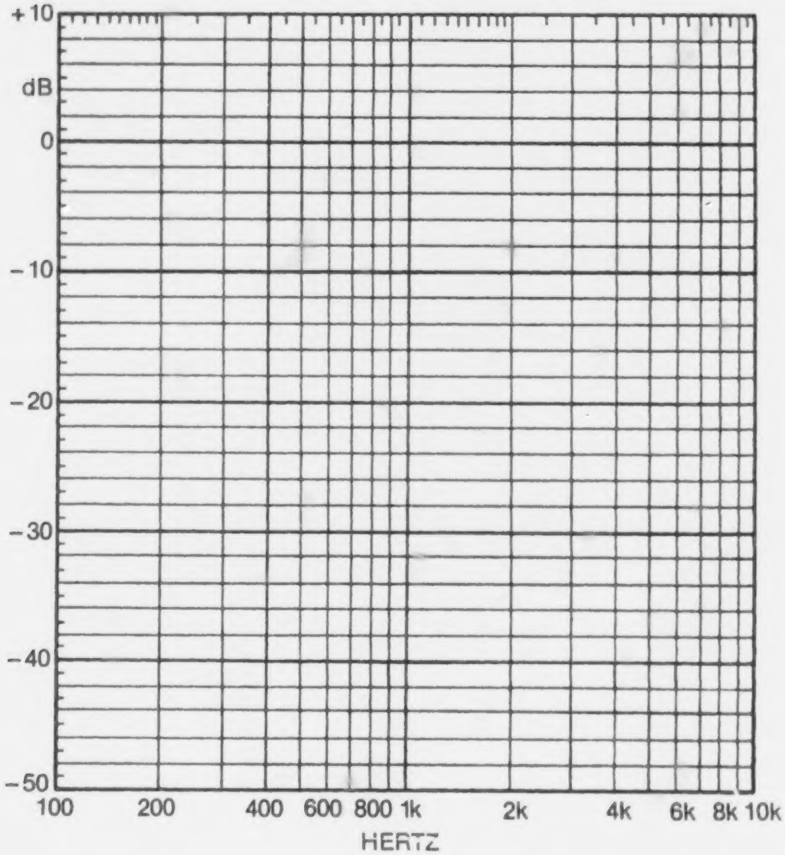
Job Sheet 6

Table 1—Frequency and Gain Values

Input Frequency	V_{in}	V_{out}	Voltage Gain Ratio	Decibel Gain
100 Hz				
200 Hz				
400 Hz				
600 Hz				
800 Hz				
1,000 Hz				
2,000 Hz				
4,000 Hz				
6,000 Hz				
8,000 Hz				
10,000 Hz				

Job Sheet 6

Graph 1—Frequency Response Curve



Linear Integrated Devices and Circuits
Unit 2

Job Sheet 7— Construct and Test a Timer Circuit

Name ______________________ Attempt Number __________

Date ______________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedures were done correctly	______
• Equipment was properly connected and operated	______
• Measurements were accurate	______
• Student demonstrated an understanding of the applicable principles	______

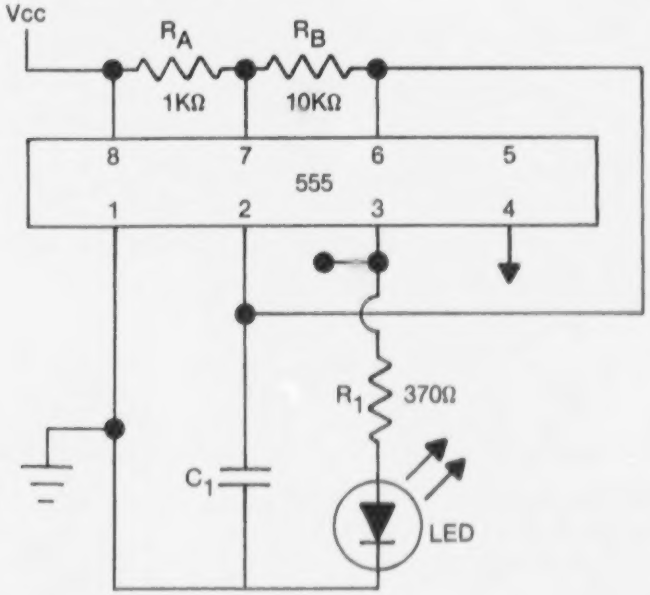
Introduction: We encounter timer circuits throughout our day, beginning with the alarm that may have gotten your day started and the snooze alarm that may have delayed the start of your day a bit longer. Traffic signals, appliances, computers, and all sorts of electronic equipment use timers to ensure that events happen when they are supposed to and last a specified period of time. Consequently, technicians are often required to work with timer circuits and to verify their operation. In this job sheet, you will be working with one of the most popular IC timers, the LM555.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Oscilloscope
- Test leads
- DC power supply, +5 volts
- LM555 timer, or equivalent
- 1 Kohm resistor, ¼-watt
- 10 Kohm resistor, ¼-watt
- 270 Kohm resistor, ¼-watt
- 10 μF capacitor, 15 volts
- 100 Kohm trim potentiometer
- Light-emitting diode
- Conductor
- Mounting surface and hardware
- Pencil and paper

- Table at end of job sheet
- Graph paper
- Circuit drawing



B. Procedure

☐ 1. Assemble the drawing per drawing, but do **not** apply power.

Note: The potentiometer will be used later in the project.

☐ 2. Calculate and record the frequency expected from the circuit using the equation

$$f = \frac{1.46}{(R_A + 2R_B) \times C_1}$$

☐ 3. Calculate and record the duty cycle using the equation

$$\text{Duty cycle} = \frac{R_B}{R_A + 2R_B}$$

☐ 4. Energize the circuit.

☐ 5. Verify that the LED flashes.

Note: If the LED does not flash, check the circuit for problems. If unable to correct the problem, contact your instructor.

Job Sheet 7

☐ 6. Check the output of pin 3 using the oscilloscope.

☐ 7. Sketch the output waveform, noting its frequency.

☐ 8. Estimate and record the duty cycle based on the ratio between when the time that the output is high versus the overall duration of a cycle.

☐ 9. Remove power from the circuit.

☐ 10. Replace R_B with the potentiometer wired as a variable resistor.

☐ 11. Energize the circuit.

☐ 12. Vary the potentiometer over its full range and record frequency values for the following points:

- What is the lowest frequency at which the circuit will operate?
- What is the highest frequency at which the circuit will operate?
- At what frequency is the duty cycle approximately 50 percent?

☐ 13. Remove power from the circuit.

☐ 14. Discuss your results with your instructor; be prepared to discuss the following points:

- How did the measured values for frequencies and duty cycle compare with your computed values?
- What is the correlation between duty cycle and the flashing of the LED?
- What do the values obtained at Step 12 tell you about the operation of the circuit?
- Would your results have been different at Step 12 if the potentiometer had been used to replace R_A?

☐ 15. Disassemble circuit and return equipment and materials to their proper storage location.

Evaluator's comments: ______________________________

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Job Sheet 7

Data Table 1

	Frequency	Duty Cycle
Calculated:		
Observed:		

Waveform sketch:

Data Table 2—Using Variable Resistor Configuration

Characteristic	Value
Lowest operating frequency	
Highest operating frequency	
50-percent duty cycle frequency	

Linear Integrated Devices and Circuits
Unit 2

Job Sheet 8—Troubleshoot Linear Circuits

Name ______________________ Attempt Number __________

Date ______________________ Overall Rating __________

Evaluation criteria	**Rating**
• Troubleshooting procedure was well designed	______
• Equipment was used correctly	______
• Correct problems were identified	______
• Problems were correctly repaired	______

Introduction: For this job sheet, your instructor will provide you with an IC device or circuit that has one or more problems. Those problems may be defective components, shorts, opens, incorrect wiring, and other problems that an electronics technician is likely to encounter in this type of circuit. Using what you have learned about troubleshooting, component testing, and IC circuit operation, you will be required to design a troubleshooting procedure for the circuit and then carry out that procedure to identify and correct problems in the circuit.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- IC circuit or device provided by instructor
- Paper and pencil
- Equipment as required by troubleshooting procedure
- Materials as required by troubleshooting procedure

B. Procedure

☐ 1. Examine device for preliminary troubleshooting assessment.

☐ 2. Define troubleshooting procedure in writing.

☐ 3. Discuss troubleshooting procedure with instructor.

☐ 4. Conduct troubleshooting procedure.

Job Sheet 8

☐ 5. Identify problems and record results of troubleshooting.

☐ 6. Repair equipment to return to operational state.

☐ 7. Verify that repair has returned equipment to an operational state.

☐ 8. Discuss the problem and your response with your instructor.

☐ 9. Return equipment and materials to their proper storage location.

Evaluator's comments: ____

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Power Supplies
Unit 3

Objective Sheet

Unit Objective

After completing this unit, the student should be able to discuss the construction and operation of power supplies and be able to construct and test power supplies. The student should demonstrate these competencies by completing the assignment sheets and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms associated with power supplies to their correct definitions.
2. Match major power supply components to their general function.
3. Match power supply circuits to their correct purposes.
4. State the function of a bipolar power supply.
5. Complete statements about the characteristics of a half-wave rectifier circuit.
6. Complete statements about the characteristics of a full-wave rectifier circuit.
7. Complete statements about the characteristics of a bridge rectifier circuit.
8. Distinguish between the output of combination rectifier circuits.
9. Match basic configurations of filter circuits to their correct features.
10. State the equation for calculating ripple factor.
11. Identify three basic voltage multiplier circuits.
12. State the equation for calculating regulation.
13. Classify regulator configurations as series or shunt regulators.
14. Describe the operation of a feedback regulator.
15. Complete statements about the characteristics of switching regulators.
16. Identify protection circuits by their schematic diagrams.

Objective Sheet

17. Arrange in order the steps for troubleshooting power supplies.
18. Calculate average voltages. (Assignment Sheet 1)
19. Calculate rms values. (Assignment Sheet 2)
20. Calculate ripple factors and percent regulation. (Assignment Sheet 3)
21. Construct and test a voltage doubler circuit. (Job Sheet 1)
22. Construct and test a capacitor filter circuit. (Job Sheet 2)
23. Construct and test a Pi-section filter circuit. (Job Sheet 3)
24. Construct and test a zener regulator. (Job Sheet 4)
25. Troubleshoot power supplies. (Job Sheet 5)

Power Supplies
Unit 3

Information Sheet

1. **Terms and definitions**

   a. **Bleeder resistor**—Component connected across filter capacitors to drain charge when the circuit is de-energized

   b. **Choke**—Inductor used in a DC power supply to reduce ripple at the output

   c. **Crowbar**—Protection circuit used to turn off a power supply in the event of excessive voltage

   d. **Current limiting**—Process of components within a circuit by which they prevent the current from exceeding a set amount

   e. **Filter**—Circuit or device used to minimize ripple in a power supply output

   f. **Percent regulation**—Comparison of the no-load voltage to the full-load voltage of a power supply expressed as a percentage of full-load voltage

   g. **Percent ripple**—Comparison of the variation of a DC power supply or rectifier output expressed as a percentage of the average voltage

   h. **Power supply**—Device or circuit that provides a specific type of electrical output by transforming an electrical input or other form of energy

   Examples: Battery, generator, AC to DC converter

   i. **Rectifier circuit**—Circuit or device that changes AC voltage into pulsating DC voltage

   j. **Reference**—Signal with a specific or desired value in one or more characteristics (voltage, current, frequency, phasing, amplitude, etc.) to which other signals are compared

   k. **Regulator**—Circuit or device that serves to keep voltage or current output at a fairly constant level despite changes in input voltage or load demand

   l. **Ripple**—Variations in the DC output of a rectifier as a result of the conversion from AC input

   m. **Sample**—To examine a characteristic of a signal in order to compare it to other signals or defined standards

Information Sheet

n. **Series regulator**—Controller wired in line with the load that provides control by varying the resistance between the power supply and the load

o. **Shunt regulator**—Controller wired parallel to the load that provides control by bypassing excessive current and by varying total current through a series resistance

2. Functions of major power supply components

a. Transformer—Steps AC voltages up or down and may provide circuit isolation

Note: Some power supply transformers are equipped with multiple taps so that voltage output can be varied. Some rectifier circuits require a center-tapped output.

b. Diodes

- Conventional diode—Rectifies AC
- Zener diode—Sets reference voltage and regulates output
- SCR—Serves as controllable rectifier and often as a switch
- Triac—Varies AC voltage levels by switching on and off

c. Capacitor—Filters pulsating DC

d. Inductor—Filters pulsating DC

e. Transistor—Regulates voltage or current and serves as a comparator for output and reference signals

3. Purposes of power supply circuits

a. Sample circuit—Measures portion of supply voltage to use as feedback for the control circuitry

Example: Voltage divider circuit

b. Reference circuit—Maintains constant voltage for comparison by control circuitry

Examples: Zener diode or IC

c. Comparator circuit—Monitors voltages for errors and, upon error detection, produces a correction voltage for the compensating circuitry

Example: Transistor

Information Sheet

d. Error amplifier—Boosts correction voltage to a power level sufficient to operate the compensating circuitry

Example: Transistor

e. Control circuitry—Regulates the supply output

Example: Transistor

f. Filter—Reduces ripple and noise

Examples: Capacitor, choke circuit

g. Rectifier—Transforms AC into pulsating DC

Example: Bridge circuit

h. Voltage controller—Changes voltage level

Examples: Transformers, voltage multipliers

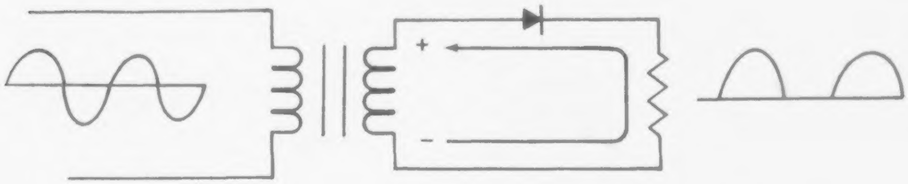
i. Adjust circuitry—Allows variation of output

Example: Variable resistor

4. **Function of a bipolar power supply**—Provides both positive and negative DC output

5. **Characteristics of a half-wave rectifier circuit**

a. Pulsating DC flows through the circuit during one-half of each AC input cycle.



b. The frequency of the output pulses is equal to the frequency of the AC input.

c. Output voltage polarity may be either positive or negative with respect to ground.

Information Sheet

d. The effective (rms) voltage output is calculated with the equation

$E_{rms} = E_{peak} \times 0.707$

Note: The constant 0.707 is $\frac{\sqrt{2}}{2}$.

e. The peak voltage output is calculated with the equation

$E_{peak} = E_{rms} \times 1.414$

Note: The constant 1.414 is $\sqrt{2}$.

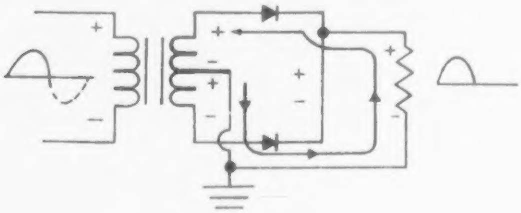
f. The average voltage output is calculated with the equation

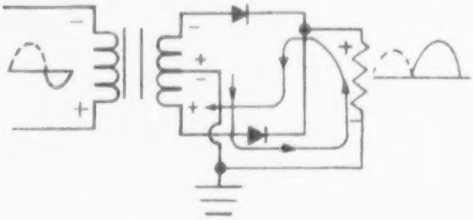
$E_{avg} = E_{peak} \times 0.318$

Note: The constant 0.318 is $\frac{1}{\pi}$.

6. Characteristics of a full-wave rectifier circuit

a. Pulsating DC flows through the circuit during the full AC input cycle.





b. The frequency of the output pulses is equal to twice the frequency of the AC input.

c. Output voltage polarity may be reversed by reversing the direction of the diodes.

Information Sheet

d. The effective (rms) voltage output is calculated with the equation

$E_{rms} = E_{peak} \times 0.707$

e. The peak voltage output is calculated with the equation

$E_{peak} = E_{rms} \times 1.414$

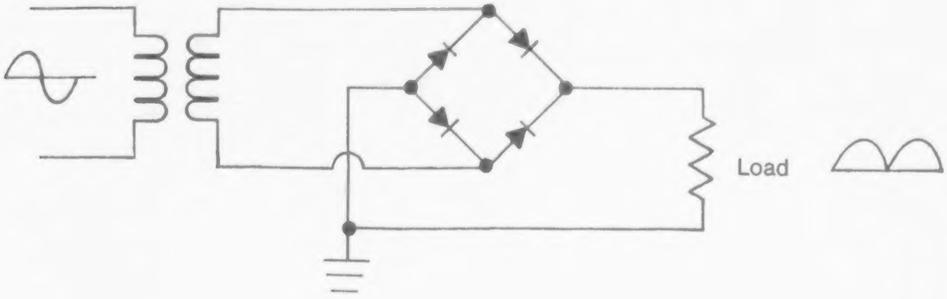
f. The average voltage output is calculated with the equation

$E_{avg} = E_{peak} \times 0.637$

Note: The constant 0.637 is $\frac{2}{\pi}$.

7. Characteristics of a bridge rectifier circuit

a. Pulsating DC flows through the circuit during the full AC input cycle.



b. The frequency of the output pulses is equal to twice the frequency of the AC input.

c. Output voltage may be either positive or negative and depends on the arrangement of the diodes in the bridge.

d. The effective (rms) voltage output is calculated with the equation

$E_{rms} = E_{peak} \times 0.707$

e. The peak voltage output is calculated with the equation

$E_{peak} = E_{rms} \times 1.414$

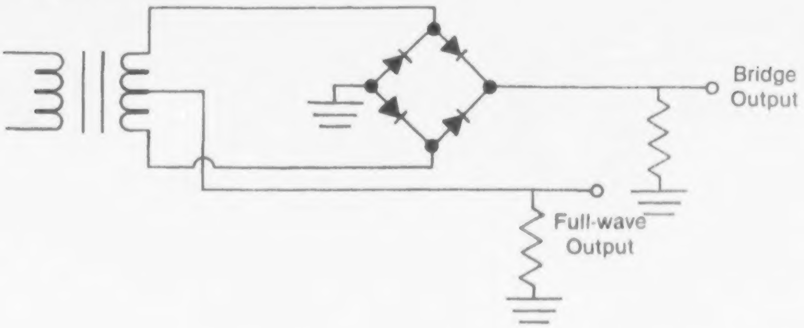
f. The average voltage output is calculated with the equation

$E_{avg} = E_{peak} \times 0.637$

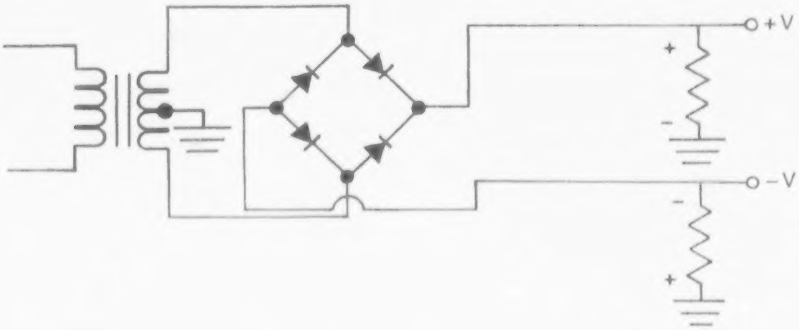
Information Sheet

8. Outputs of combination rectifier circuits

a. A full-wave/bridge combination power supply may be used to provide two DC voltage sources.



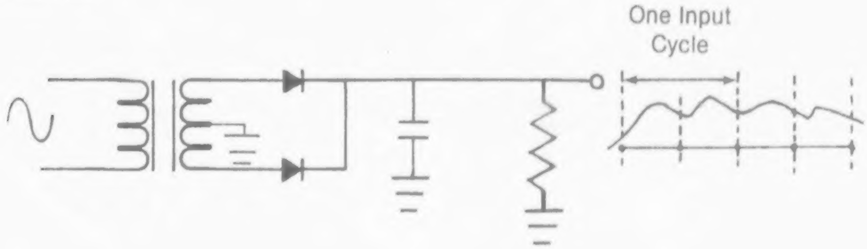
b. A full-wave/full wave combination power supply may be used to provide two outputs of opposite polarity.



9. Features of configurations of filter circuits

a. Capacitor filter—Uses a capacitor and resistor to provide an economical, simple filter that is acceptable where the load does not require an extremely smooth DC voltage

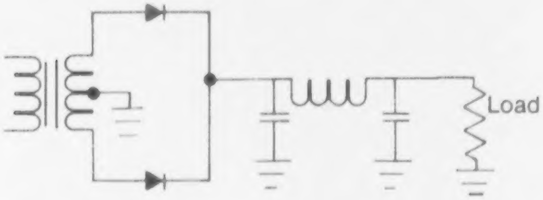
Example:



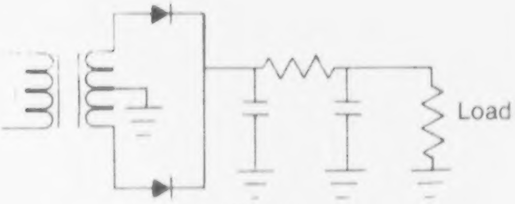
Information Sheet

b. Pi-section filter—Uses two capacitors and an inductor or two capacitors and a resistor in a low-pass arrangement to produce a fairly smooth output suitable for use with low currents

Examples:



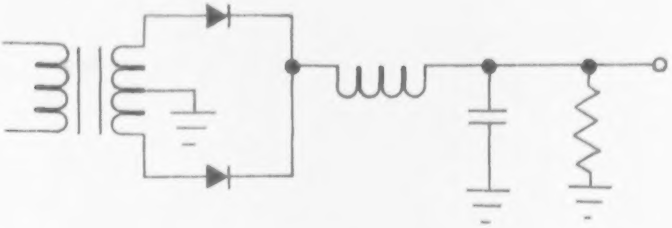
LC Filter



RC Filter

c. L-section filter—Uses a capacitor and inductor suitable for high current applications

Example:



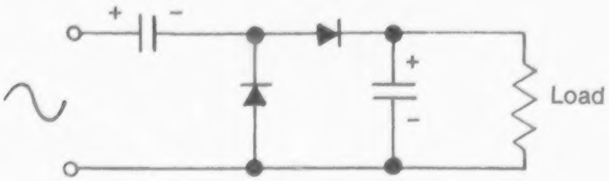
10. **Ripple factor**—Representation of the efficiency of a filter as calculated by the equation

$$\% \text{ ripple} = \frac{E_{rms}}{E_{avg}} \times 100$$

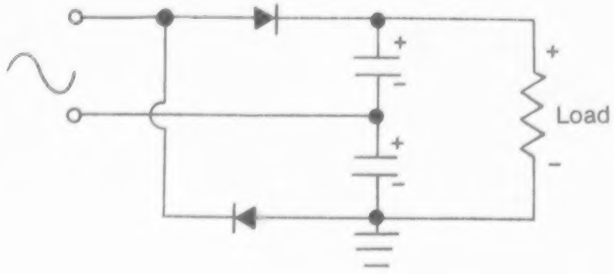
11. Basic voltage multiplier circuits

a. Half-wave voltage doubler

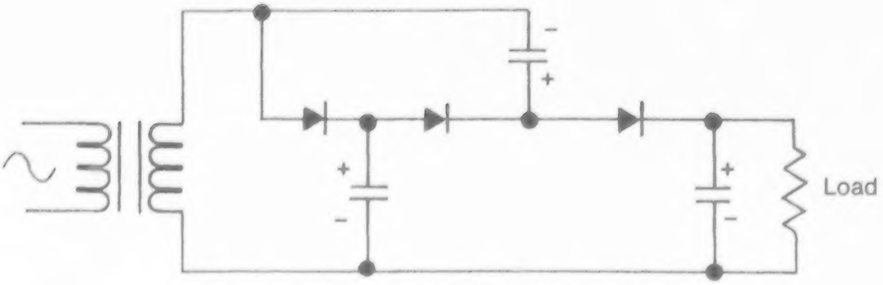
Note: Although the half-wave voltage doubler provides a DC output that is approximately twice the value of the AC input, the ripple voltage is difficult to filter and the output capacitor must have a voltage rating at least twice the peak value of the AC input.



b. Full-wave voltage doubler



c. Voltage tripler



Information Sheet

12. **Regulation**—Measure of the ability of a power supply to hold a constant output under varying loads and with changing input as calculated by the equation:

$$\text{Regulation} = \frac{\Delta V}{V_{\text{full load}}} \times 100$$

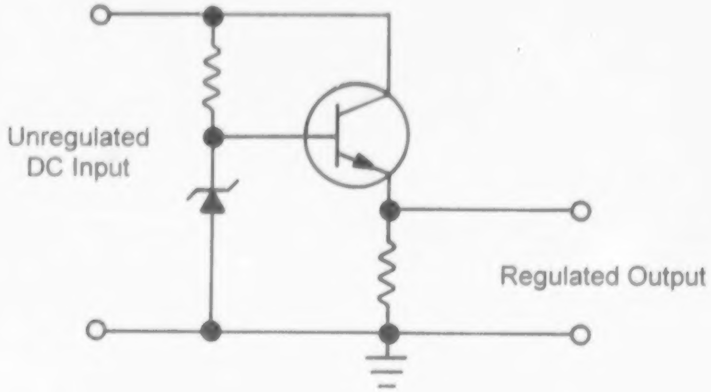
Note: The change in voltage represented by ΔV is the difference between voltage at minimum load and that at full load.

13. **Series and shunt regulator configurations**

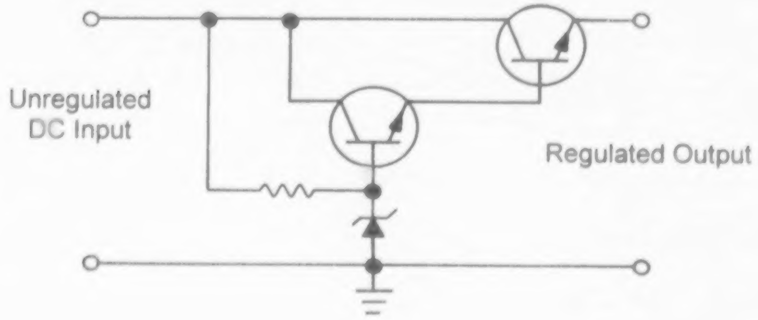
Note: In Unit 1, you learned how semiconductor devices could be used to assemble voltage regulators. In this objective, you will build on that knowledge to see how such configurations can be classified by whether they use a series or shunt circuit.

a. Series

- Emitter-follower series regulator

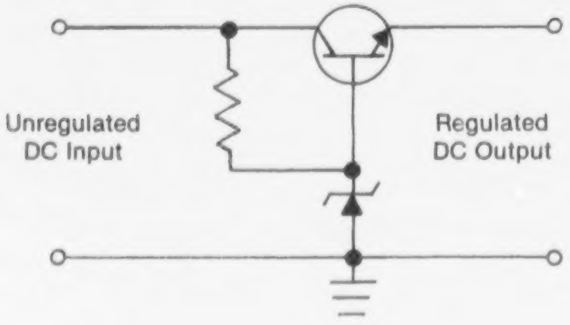


- Darlington configuration series regulator



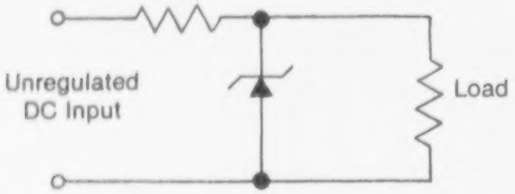
Information Sheet

- Amplified zener series regulator

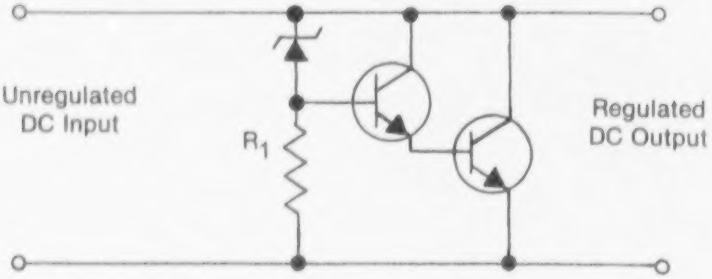

Unregulated
DC Input
Regulated
DC Output

b. Shunt

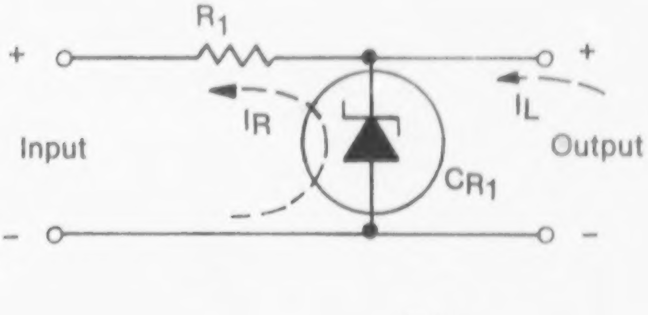
- Zener regulator


Unregulated
DC Input
Load

- Amplified zener shunt regulator


Unregulated
DC Input
R_1
Regulated
DC Output

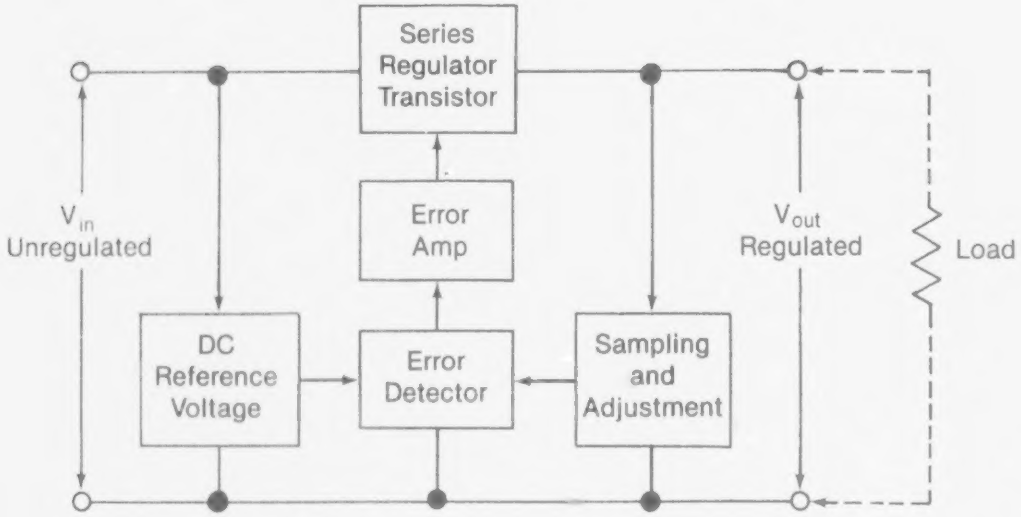
- Transistor shunt regulator


R_1
+
+
I_R
I_L
Input
Output
CR_1
–
–

Information Sheet

14. Operation of a feedback regulator

Example:


Series Regulator Transistor
Error Amp
Error Detector
DC Reference Voltage
Sampling and Adjustment
V_{in} Unregulated
V_{out} Regulated
Load

a. The DC reference voltage is generally collected through a zener diode and fed to the error detector.

b. The sampling and adjustment circuit is usually a voltage divider connected across the output branches and provides feedback to the error detector.

c. The error detector compares the reference input signal and the sampled output signal and provides an output to the regulator transistor.

d. The error voltage amplifier amplifies the output of the error detector and routes the signal to the regulator transistor.

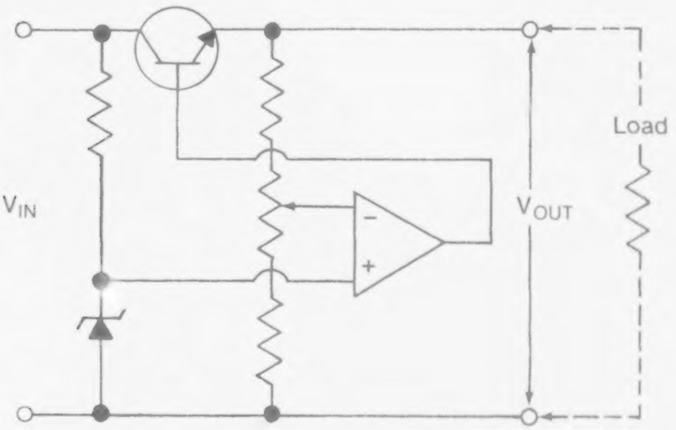
e. The error voltage controls the conductivity of the regulator transistor to adjust input signal flow in response to the sampled output.

Information Sheet

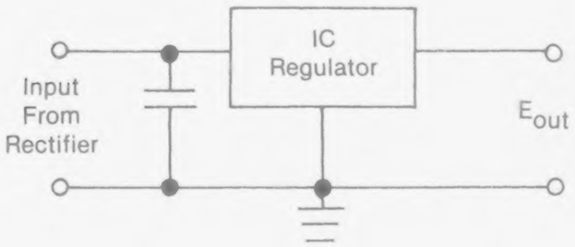
f. The feedback regulator may consist of discrete components, discrete and linear integrated components, or a single IC.

Examples:

Feedback regulator with an op-amp serving as the error detector and error voltage amplifier



Three-terminal IC feedback regulator



15. Characteristics of switching regulators

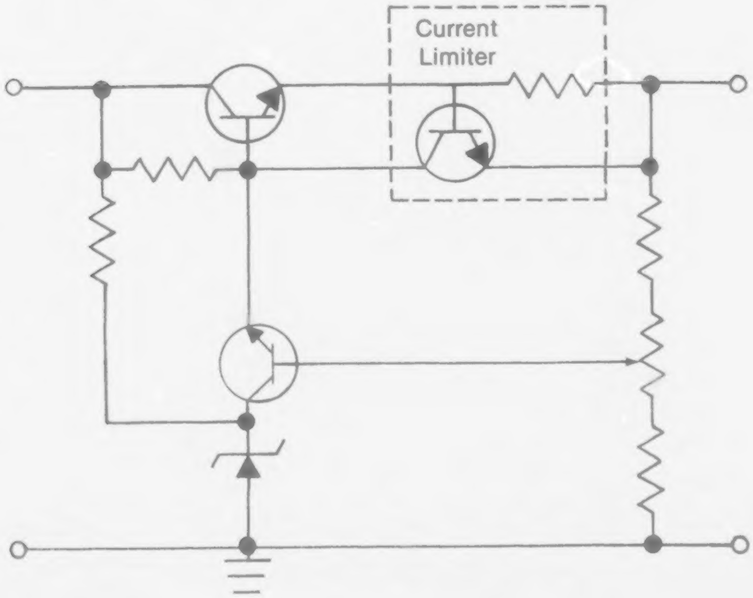
a. The purpose of a switching regulator is to improve the efficiency of the regulator circuit by using a pulsing technique.

b. Switching regulators may be operated in step-up, step-down, or inverting modes.

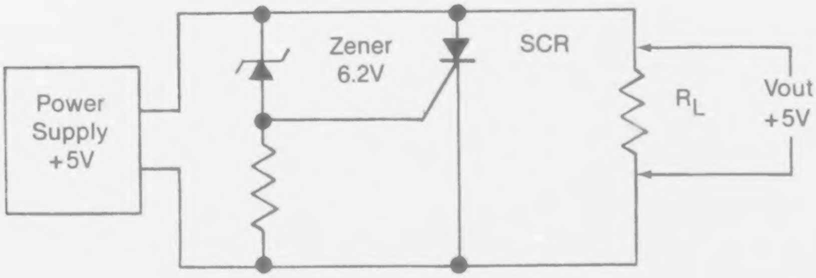
Information Sheet

16. Schematic diagrams of protection circuits

a. Current limiting circuit


Current
Limiter

b. Crowbar circuit


Power
Supply
+5V
Zener
6.2V
SCR
R_L
Vout
+5V

Information Sheet

17. Troubleshooting power supplies

a. Disconnect the load from the power supply and check to see if the problem still exists.

b. Check filtering capacitors for charging.

c. If the capacitor is not charging, disconnect one lead and check again for charging.

Note: If the capacitor is shorted, replace it.

d. Check rectifier diodes for proper operation.

e. Check all resistors for proper value.

f. Check transistors for proper operation.

g. If all components are working correctly, disconnect the rectifier from the transformer and turn power on.

Note: If AC voltage is not present on the secondary, replace the transformer.

Power Supplies
Unit 3

Assignment Sheet 1—Calculate Average Voltages

Name ______________________________ Overall Rating ____________

Evaluation criteria **Rating**

- Directions have been followed ________
- Minimum of 80 percent of answers are correct ________

Note: Each correct answer is worth 20 points.

Introduction: The output of a power supply must be compatible with the load requirements. Too large of an output may overheat the load or cause it to run too fast, while too little output may fail to power the load. Two important characteristics that determine whether the output is suitable are average voltage and ripple, which is the variation from average voltage. In order to assess whether a power supply output is suitable, an electronics technician must be able to calculate both of these values. In this assignment sheet, you will get to practice calculating average voltage for various rectifier circuits, while Assignment Sheet 3 provides practice in determining ripple.

There are two formulas to remember when calculating average voltage. One applies to half-wave rectifier circuits and is

$$E_{avg} = E_{peak} \times 0.318$$

The second formula applies to full-wave and bridge rectifier circuits. This equation is

$$E_{avg} = E_{peak} \times 0.637$$

Thus, if a half-wave circuit has a peak voltage of 4 volts, its average voltage would be

$$E_{avg} = 4 \text{ volts} \times 0.318 = 1.272 \text{ volts}$$

Similarly, if a full-wave rectifier circuit's peak voltage is 12 volts, its average voltage is calculated as

$$E_{avg} = 12 \text{ volts} \times 0.637 = 7.644 \text{ volts}$$

Assignment Sheet 1

If the technician knows the effective voltage rather than the peak voltage, it will be necessary to convert the rms value to peak voltage. For all three circuit configurations, the formula for this calculation is

$$E_{peak} = E_{rms} \times 1.414$$

Therefore, to calculate the average voltage for a bridge circuit with an effective voltage of 9.6 volts, the process would be

$$E_{peak} = 9.6 \text{ volts} \times 1.414 = 13.6 \text{ volts}$$

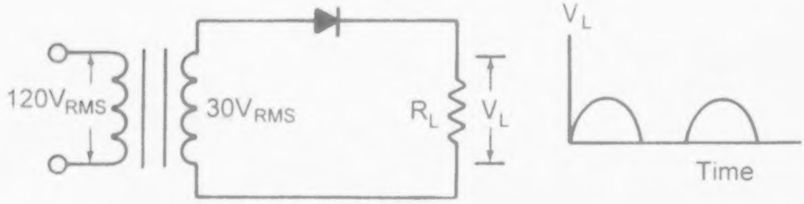
$$E_{avg} = 13.6 \text{ volts} \times 0.637 = 8.6 \text{ volts}$$

Directions: Study the schematics and problems given below and solve for the requested value. Write your answers in the spaces provided.

Note: Round your answer to the nearest tenth.

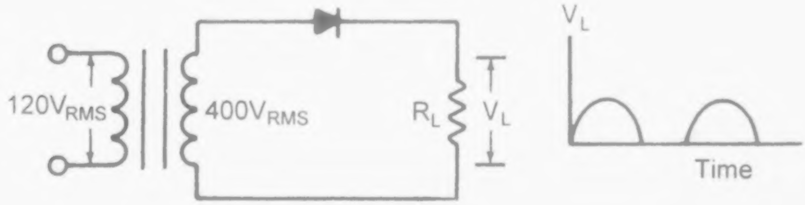
1. What is the average DC voltage for the circuit below?

____



2. What is the average DC voltage for the circuit below?

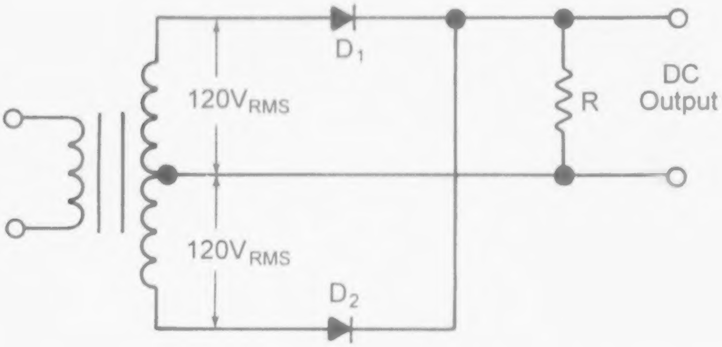
____



Assignment Sheet 1

3. What is the average DC voltage for the circuit below?

____


D1
120V RMS
120V RMS
D2
R
DC Output

4. If a half-wave circuit has a peak voltage of 32 volts, what is the average voltage?

____

5. If a bridge circuit has a peak voltage of 24 volts, what is the average voltage?

____

Power Supplies
Unit 3

Assignment Sheet 2—Calculate RMS Values

Name ______________________________ Overall Rating ____________

Evaluation criteria	Rating
• Directions have been followed	________
• Minimum of 80 percent of answers are correct	________
Note: Each correct answer is worth 20 points.	

Introduction: In the previous assignment sheet, you used rms values and peak values to determine average voltages. Sometimes the technician does not know the rms value and must calculate it from other known values. Generally, the known value is either peak voltage or average voltage. For rectifier circuits, the equation for converting peak voltage to rms voltage is

$$E_{peak} = E_{rms} \times 1.414$$

Thus, if the peak voltage is known, the technician can determine the rms value by dividing the peak value by 1.414. Therefore, the rms voltage of a rectifier circuit with a peak voltage of 12 volts can be calculated as

$$\begin{aligned} E_{rms} &= E_{peak} \div 1.414 \\ &= 12 \text{ volts} \div 1.414 \\ &= 8.5 \text{ volts} \end{aligned}$$

The formula for converting average voltage to effective voltage depends on whether the circuit is a half-wave or full-wave rectifier. As noted in the information sheet, the equation for converting a half-wave rectifier's peak voltage to average voltage is

$$E_{avg} = E_{peak} \times 0.318$$

If the average voltage is known, then peak voltage can be computed as

$$E_{peak} = E_{avg} \div 0.318$$

The corresponding equations for a full-wave rectifier are

$$E_{avg} = E_{peak} \times 0.637 \quad \text{and} \quad E_{peak} = E_{avg} \div 0.637$$

Assignment Sheet 2

To convert average voltage to rms voltage, a technician must use a two-step process, first converting average voltage to peak voltage and then converting peak voltage to rms. For example, if a half-wave rectifier has an average voltage of 9 volts, begin by converting average voltage to peak voltage using the half-wave formula:

$$E_{peak} = E_{avg} \div 0.318$$
$$= 9 \text{ volts} \div 0.318$$
$$= 28.3 \text{ volts}$$

Then substitute the calculated peak voltage in the formula to compute rms voltage. Thus,

$$E_{rms} = E_{peak} \div 1.414$$
$$= 28.3 \text{ volts} \div 1.414$$
$$= 20 \text{ volts}$$

Directions: Read the problems and determine the values requested. Write your answers in the spaces provided.

Note: Round your answer to the nearest tenth.

1. What is the rms voltage for a half-wave rectifier with a peak voltage of 13.6 volts?

   ____

2. What is the rms voltage for a bridge rectifier circuit with an average output of 24 volts?

   ____

3. What is the rms voltage in a full-wave rectifier circuit with a peak voltage of 18.5 volts?

   ____

4. What is the rms voltage of a half-wave rectifier circuit with an average voltage of 6.2 volts?

   ____

5. What is the rms voltage of a half-wave rectifier circuit with a peak voltage of 36.4 volts?

   ____

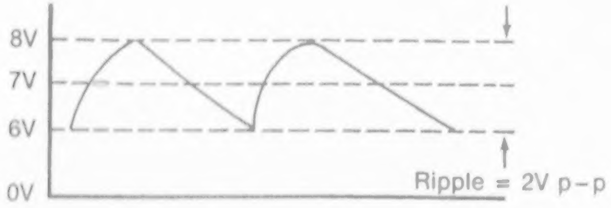
Power Supplies
Unit 3

Assignment Sheet 3—Calculate Ripple Factors and Percent Regulation

Name ______________________________ Overall Rating ____________

Evaluation criteria	**Rating**
• Directions have been followed	________
• Minimum of 80 percent of answers are correct	________
Note: Each correct answer is worth 10 points.	

Introduction: Ripple is the amount of AC characteristic left in the output of a rectifier, as shown in the figure below. The more the output signal deviates from a straight-line output, the greater the ripple. Ripple is especially important in electronics because the variations in a rectifier output can easily be great enough to be read as changes in input signals. For example, excessive ripple could cause a transistor to switch from on to off or off to on when the operational requirement is for the transistor to remain in one state or the other.



Ripple factor is calculated as the percentage of rms ripple voltage compared to the average voltage. The formula for computing ripple factor is

$$\% \text{ ripple} = \frac{E_{rms}}{E_{avg}} \times 100$$

Consider the signal shown in the figure above. The ripple is 2 volts peak-to-peak or 1 volt peak, while the average voltage is 7 volts. We can convert the peak voltage to rms by multiplying by 0.707, giving us an rms voltage of 0.707 volts. Thus, the percent of ripple would be

$$\% \text{ ripple} = \frac{0.707 \text{ volts}}{7 \text{ volts}} \times 100 = 0.1 \times 100 = 10$$

Assignment Sheet 3

Similarly, regulation is the ability of the power supply to hold a constant output—no matter what the ripple factor is—as the input and load varies. For example, commercial power can fluctuate considerably with noise and transient spikes while operating a piece of equipment, such as a VCR. The VCR's load requirements can also vary depending on its functions, such as playing and recording at different speeds, fast-forward, pause, and rewind. A regulated power supply attempts to maintain its output as close as possible to a specific level even as the input and load demands change. Regulation is computed as a percentage of the full-load value as compared to the difference between the full-load and no-load voltages.

$$\text{Regulation} = \frac{\Delta V}{V_{\text{full load}}} \times 100$$

For example, if a circuit operates at 10 volts under full load and 12 volts with no load, its regulation would be

$$\text{Regulation} = \frac{2 \text{ volts}}{10 \text{ volts}} \times 100 = 0.2 \times 100 = 20$$

Directions: Read the problems below and determine the values requested. Write your answers in the spaces provided.

1. A power supply has an input of 120 volts. Its no-load average output is 30 volts with a ripple of 10 volts-rms. Under full-load, its output is 28.4 volts.

   a. What is its ripple factor? ______________________

   b. What is its regulation? ______________________

2. A power supply puts out 15 voltages with no load and 13.8 under full load. Its ripple is 0.05 volts rms.

   a. What is its ripple factor? ______________________

   b. What is its regulation? ______________________

3. Under load, a power supply provides 22 volts, while without a load its average output is 24 volts with a peak voltage of 26.2 volts.

   a. What is its ripple factor? ______________________

   b. What is its regulation? ______________________

4. A circuit must operate on a power supply output of 17.4 to 18.6 volts. What is the maximum allowable ripple factor for a power supply that yields an average output of 18 volts?

   ____

Assignment Sheet 3

5. For a given circuit to operate, there can be no more than a 3-volt difference between its no-load and full-load conditions. What is the maximum regulation factor allowed for a power supply designed to provide the 28-volt output required to drive the circuit?

____

6. A circuit is operating at 32 volts average with a ripple of 3.6 volts rms. When a load is applied, the output drops to 29.7 volts. When the load is removed, the output returns to 32 volts.

   a. What is its ripple factor? ____________________________________

   b. What is its regulation? ____________________________________

Power Supplies
Unit 3

Job Sheet 1— Construct and Test a Voltage-Doubler Circuit

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	Rating
• Procedure was done correctly	________
• Equipment was used correctly	________
• Circuit was correctly wired	________
• Student demonstrated an understanding of the applicable principles	________

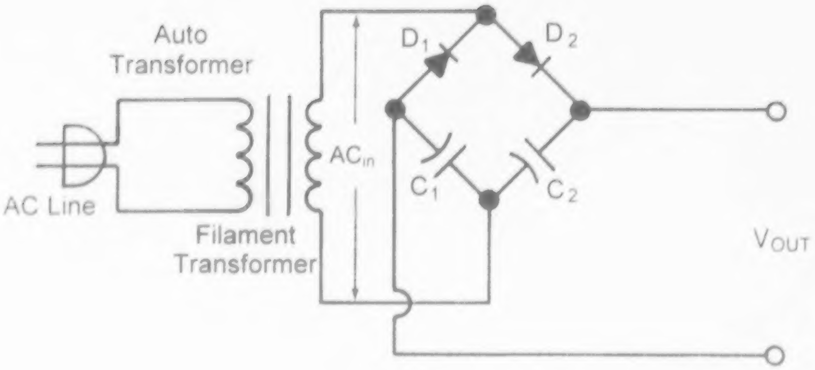
Introduction: Transformers are commonly used in electrical circuits to increase or decrease voltages. However, transformers can be expensive and heavy and often cause interference due to induction. Their output capabilities frequently exceed what is required in an electronics circuit. Therefore, many electronic circuits use voltage multipliers to step up the voltage without using a transformer. For that reason, electronic technicians need to understand the operation of voltage multipliers. In this circuit, you will construct and test a voltage doubler.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Oscilloscope
- Multimeter
- Test leads
- Lower-power filament transformer, 120-volt primary
- Two silicon diodes, 1N4004 or equivalent
- Two 20 μF capacitors, 450-volt
- Low-voltage conductor
- Mounting surface and hardware
- Pencil and paper
- Graph paper
- Protractor
- Circuit drawing on next page

Job Sheet 1



B. Procedure

☐ 1. Assemble circuit per drawing, but do **not** apply power.

☐ 2. Have your instructor check your circuit.

☐ 3. Energize the circuit.

☐ 4. Measure and record the voltage across C_1.

☐ 5. Measure and record the voltage across C_2.

☐ 6. Measure and record the voltage across the output.

☐ 7. Measure and record the voltage across secondary winding of the filament transformer.

☐ 8. Use the oscilloscope to measure the input voltage.

☐ 9. Sketch the input waveform.

☐ 10. Repeat Steps 8 and 9 for the output.

☐ 11. Remove power from the circuit.

☐ 12. Discuss your results with your instructor; be prepared to discuss the following points:

- What is the purpose of each portion of the circuit?
- What is the relationship between the filament transformer output and the voltage doubler output? Did the voltage double? Why or why not?

Job Sheet 1

- How does the arrangement of capacitors and diodes produce an increase in voltage?
- How could the circuit be changed to create a voltage tripler?

☐ 13. Disassemble circuit and return equipment and materials to their proper storage location.

Evaluator's comments: ______________________________

Power Supplies
Unit 3

Job Sheet 2— Construct and Test a Capacitor Filter Circuit

Name ______________________ Attempt Number __________

Date ______________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedure was done correctly	________
• Equipment was used correctly	________
• Circuit was correctly wired	________
• Student demonstrated an understanding of the applicable principles	________

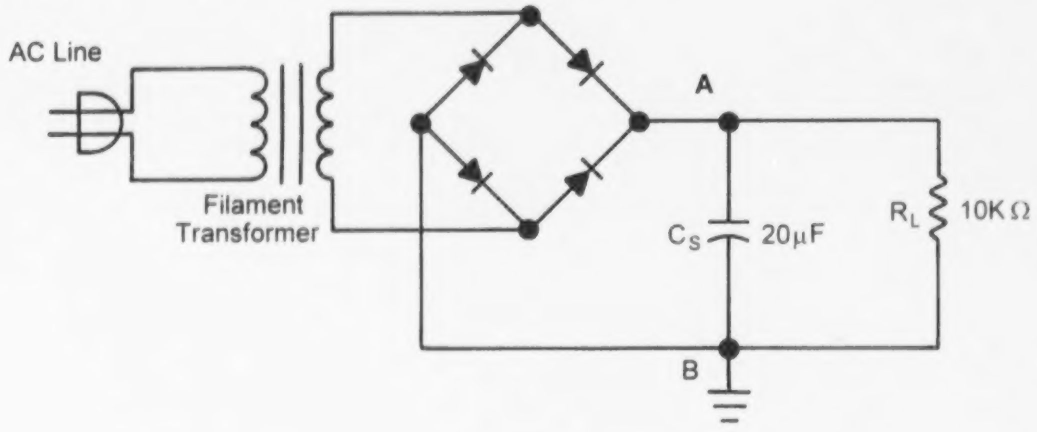
Introduction: Filter circuits are important in electronic equipment for two major reasons. First, they are able to condition signals to eliminate noise. Secondly, they are able to block some signals so that circuits can provide selective conductivity. This is an important function of filters in power supplies. Filters reduce ripple and help to provide a more constant output signal. Because excessive ripple can wreak havoc with electronic components, the role of filters in power supplies is crucial. In this job sheet, you will examine the operation of a capacitor filter, while in the next job sheet you will construct and test a pi-section filter.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Oscilloscope
- Multimeter
- Test leads
- Low-power filament transformer, 120-volt primary
- 1 Kohm resistor, ½-watt
- 10 Kohm resistor, ½-watt
- 20 μF capacitor, 25 volt or greater
- Low-voltage conductor
- Mounting surface and hardware
- Pencil and paper
- Graph paper
- Protractor
- Table at end of this job sheet
- Circuit drawing on the next page

Job Sheet 2



B. Procedure

☐ 1. Assemble circuit per drawing except omit the capacitor branch between Points A and B; do **not** apply power.

Note: Use the 10 Kohm resistor for the first circuit configuration. The 1 Kohm resistor will be used later.

☐ 2. Have your instructor check your circuit.

☐ 3. Energize the circuit.

☐ 4. Using the multimeter, measure the voltage across the secondary of the filament transformer and record.

☐ 5. Measure and record the voltage across the load resistor.

☐ 6. Connect the oscilloscope across the load resistor and sketch the waveform.

☐ 7. Remove power from the circuit.

☐ 8. Connect the capacitor between Points A and B.

☐ 9. Repeat Steps 2-7 for the new configuration.

☐ 10. Remove the capacitor from between Points A and B.

Job Sheet 2

☐ 11. Replace the 10 Kohm resistor with the 1 Kohm resistor.

☐ 12. Repeat Steps 2-9 for the new configuration.

☐ 13. Using the output voltage observed with the 10-Kohm resistor as a no-load condition and that observed with the 1-Kohm resistor as the full-load condition, calculate regulation.

☐ 14. Discuss your results with your instructor; be prepared to discuss the following points:

- What is the purpose of each part of the circuit?
- What was the effect of adding the capacitor to the circuit?
- What was the calculated regulation? Is this an efficient filter? What could be done to improve the filter?

☐ 15. Disassemble the circuit and return equipment and materials to their proper storage location.

Evaluator's comments: ______________________________

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Job Sheet 2

Data Table

Filter Status	Secondary Output	Voltage (10-Kohm Load)	Voltage (1-Kohm Load)	Regulation (%)
No filter				
With filter				

Power Supplies
Unit 3

Job Sheet 3— Construct and Test a Pi-Section Filter Circuit

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedure was done correctly	________
• Equipment was used correctly	________
• Circuit was correctly wired	________
• Student demonstrated an understanding of the applicable principles	________

Introduction: Ribbon cables are used extensively in computers and with computer peripherals, such as printers. They provide the convenience of numerous conductors in a single cable, flexibility, and easy installation of connectors. Unlike other cables, ribbon cables even allow installation of connectors at points in the cable other than the ends. Because ribbon cable connectors pierce the insulation of the cable to contact the conductors, it is not necessary to strip the insulation.

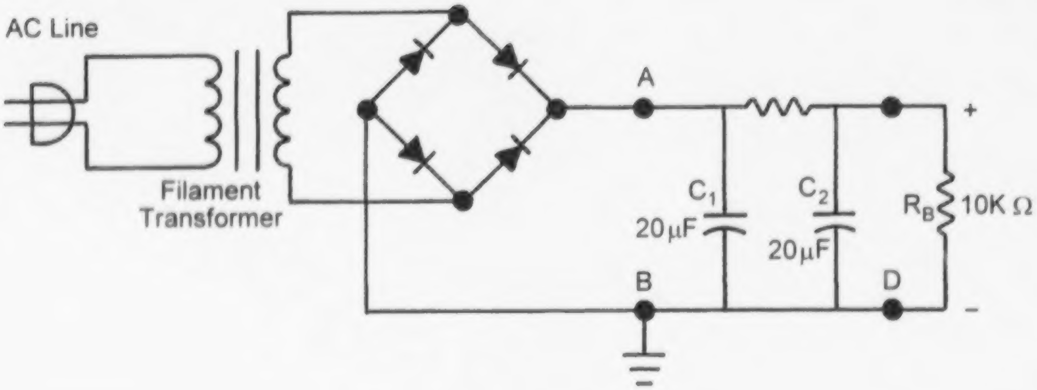
Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Oscilloscope
- Multimeter
- Test leads
- Low-power filament transformer, 120-volt primary
- 1 Kohm resistor, ½-watt
- 10 Kohm resistor, ½-watt
- 270 ohm resistor
- Two 20 μF capacitors, 25 volts or greater
- Low-voltage conductor
- Mounting surface and hardware
- Pencil and paper
- Graph paper
- Protractor
- Table at end of this job sheet

Job Sheet 3

- Circuit drawing



B Procedure

☐ 1. Assemble circuit per drawing except:

- Do **not** install filter network
- Connect load resistor to Points A and B
- Do **not** apply power

Note: Use the 10 Kohm resistor for the first circuit configuration. The 1 Kohm resistor will be used later.

☐ 2. Have your instructor check your circuit.

☐ 3. Apply power to the transformer.

☐ 4. Using the multimeter, measure the voltage across the secondary of the filament resistor and record.

☐ 5. Read and record the voltage across the load resistor.

☐ 6. Connect the oscilloscope across the load and sketch the waveform.

☐ 7. Remove power from the circuit.

☐ 8. Install the filter between Points A and B.

☐ 9. Connect the load across Points C and D of the filter circuit.

☐ 10. Repeat Steps 2-7 for the new configuration.

Job Sheet 3

☐ 11. Replace the 10 Kohm resistor with the 1 Kohm resistor.

☐ 12. Repeat Steps 2-9 for the new configuration.

☐ 13. Using the output voltage observed with the 10-Kohm resistor as a no-load condition and that observed with the 1-Kohm resistor as the full-load condition, calculate regulation.

☐ 14. Discuss your results with your instructor; be prepared to discuss the following points:

- What is the purpose of each part of the circuit?
- What was the effect of adding the capacitors to the circuit?
- What was the calculated regulation? Is this an efficient filter? What could be done to improve the filter?

☐ 15. Disassemble the circuit and return equipment and materials to their proper storage location.

Evaluator's comments: ____

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Job Sheet 3

Data Table

Filter Status	Secondary Output	Voltage (10-Kohm Load)	Voltage (1-Kohm Load)	Regulation (%)
No filter				
With filter				

Power Supplies
Unit 3

Job Sheet 4— Construct and Test a Zener Regulator

Name ______________________________ Attempt Number __________

Date ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
• Procedure was done correctly	________
• Equipment was used correctly	________
• Circuit was correctly wired	________
• Student demonstrated an understanding of the applicable principles	________

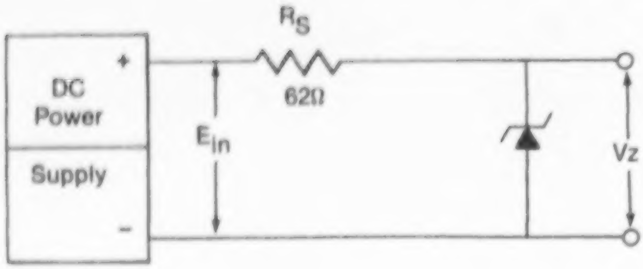
Introduction: Regulator networks help to maintain a near-constant power supply output in much the same way that a filter improves rectifier output. One of the most common regulators used in electronic circuits, either as a discrete component or internal to an IC, is the zener diode, and the zener shunt regulator in particular. In this job sheet, you will analyze the effects of a zener diode shunt regulator on the output of a power supply.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- DC power supply, 0-10 volts
- Multimeter
- Test leads
- 62 ohm resistor, 1 watt
- 5.1 volt zener diode, 1 watt
- Low-voltage conductor
- Mounting surface and hardware
- Pencil and paper
- Graph paper
- Protractor
- Table at end of this job sheet
- Circuit drawing on the next page

Job Sheet 4



B. Procedure

☐ 1. Measure and record the resistance between the anode and cathode of the diode.

☐ 2. Measure and record the resistance between the cathode and anode of the diode.

☐ 3. Assemble the circuit per the drawing, but do **not** apply power.

☐ 4. Have your instructor check your circuit.

☐ 5. Set the power supply output to 0.

☐ 6. Energize the circuit.

☐ 7. Measure and record the voltage across V_z.

☐ 8. Set the power supply output to 1 volt.

☐ 9. Repeat Steps 7 and 8 for each value on the data table.

☐ 10. Remove power from the circuit.

☐ 11. Discuss your results with your instructor; be prepared to discuss the following points:

- How does the diode regulate the power supply output?
- At what point did power regulation begin? How do you recognize that it began?
- If you needed to build a circuit that would provide power regulation beginning at 2 volts, what would you change about this circuit?

☐ 12. Disassemble the circuit and return equipment and materials to their proper storage location.

Job Sheet 4

Evaluator's comments: ____________________

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Job Sheet 4

Data Table

Power Supply Output	0	1	2	3	4	5	6	7	8	9
Circuit Output Voltage										

Power Supplies
Unit 3

Job Sheet 5—Troubleshoot Power Supplies

Name ______________________ Attempt Number ____________

Date ______________________ Overall Rating ____________

Evaluation criteria	**Rating**
• Troubleshooting procedure was well designed	________
• Equipment was used correctly	________
• Correct problems were identified	________
• Problems were correctly repaired	________

Introduction: For this job sheet, your instructor will provide you with a rectifier or power supply circuit that has one or more problems. Those problems may be defective components, shorts, opens, incorrect wiring, and other problems that an electronics technician is likely to encounter in this type of circuit. Using what you have learned about troubleshooting, component testing, and power supply operation, you will be required to design a troubleshooting procedure for the circuit and then carry out that procedure to identify and correct problems in the circuit.

Prior to beginning this procedure, you may want to review Objective 17 in the Information Sheet.

Directions: When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

A. Equipment and materials

- Power supply or rectifier circuit provided by instructor
- Paper and pencil
- Equipment as required by troubleshooting procedure
- Materials as required by troubleshooting procedure

B. Procedure

☐ 1. Examine device for preliminary troubleshooting assessment.

☐ 2. Define troubleshooting procedure in writing.

Job Sheet 5

☐ 3. Discuss troubleshooting procedure with instructor.
☐ 4. Conduct troubleshooting procedure.
☐ 5. Identify problems and record results of troubleshooting.
☐ 6. Repair equipment to return to operational state.
☐ 7. Verify that repair has returned equipment to an operational state.
☐ 8. Discuss the problem and your response with your instructor.
☐ 9. Return equipment and materials to their proper storage location.

Evaluator's comments: ______________________________